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SCIENTIFIC OPINION

Scientific Opinion on the risk posed by pathogens in food of non-animal origin. Part 2 (*Salmonella* and Norovirus in tomatoes)[1]

EFSA Panel on Biological Hazards (BIOHAZ)[2, 3]

European Food Safety Authority (EFSA), Parma, Italy

ABSTRACT

Tomatoes may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, stem removal, cutting, packaging and storage. Epidemiological data from the EU have identified one salmonellosis outbreak and one Norovirus outbreak associated with tomato consumption between 2007 and 2012. Risk factors for tomato contamination by *Salmonella* and Norovirus were considered in the context of the whole food chain. Available estimates of the *Salmonella* and Norovirus occurrence in tomatoes were evaluated together with mitigation options relating to prevention of contamination and the relevance of microbiological criteria. It was concluded that each farm environment represents a unique combination of risk factors that can influence occurrence and persistence of pathogens in tomato production. Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP), should be primary objectives of tomato producers. The current lack of data does not allow the proposal of a Hygiene Criterion for *E. coli* at primary production of tomatoes and it is also not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion. There are Food Safety Criteria for the absence of *Salmonella* in 25 g samples of ready-to-eat pre-cut tomatoes as well as in unpasteurised tomato juice placed on the market during their shelf life. A Food Safety Criterion for *Salmonella* in whole tomatoes could be considered as a tool to communicate to producers and processors that *Salmonella* should not be present in the product. Testing of tomatoes for *Salmonella* could be limited to instances where other factors indicate breaches in GAP, GHP, GMP or HACCP programmes. It is currently not possible to provide a risk base for establishing a Norovirus Food Safety Criterion for these foods.

KEY WORDS

tomatoes, microbiological criteria, microbiological risk factors, mitigation options, Norovirus, *Salmonella*

[1] On request from the European Commission, Question No EFSA-Q-2013-00177, adopted on 11 September 2014.

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SUMMARY

The European Commission asked EFSA's Panel on Biological Hazards (BIOHAZ Panel) to prepare a scientific Opinion on the public health risk posed by pathogens that may contaminate food of non-animal origin (FoNAO). The outcomes of the first and second terms of reference, addressed in a previous Opinion, were discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other three terms of reference. This is the fourth Opinion out of five and addresses the risk from *Salmonella* and Norovirus in tomatoes. The terms of reference are to: (i) identify the main risk factors for tomatoes, including agricultural production systems, origin and further processing; (ii) recommend possible specific mitigation options and to assess their effectiveness and efficiency to reduce the risk for humans posed by *Salmonella* and Norovirus in tomatoes, and (iii) recommend, if considered relevant, microbiological criteria for *Salmonella* and Norovirus in tomatoes.

Tomatoes are defined according to commercial production and consumption as the fruit from a small herbaceous plant, *Lycopersicum esculentum* Miller, which belongs to the *Solanaceae* family and grows under warm conditions. Tomatoes may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, stem removal, cutting, packaging, and storage. Tomatoes may be also subject to cooking, drying, bottling, canning and other processes, but these are outside the scope of this Opinion.

Tomatoes for fresh market are primarily produced in greenhouses, although differences in the type of production can be observed within the EU and small-scale growers still use open field-cultivation in some countries if climatic conditions allow. Tomato production in greenhouses can be carried out using soil or soil-less systems. Soil-cultivated tomatoes in greenhouses use similar techniques to those used for open field cultivation. Soil-less systems include a great diversity of processes, from the purely hydroponic, to those based on artificial mixes that contain various proportions of different substrates. Open-field tomatoes are usually cultivated using plastic mulch on raised beds. In open field production, plastic mulch can be also used to promote early fruiting, reduce competition from weeds, and to conserve moisture and fertilizer. Drip irrigation is used most frequently in conjunction with plastic mulch.

Tomatoes are usually harvested by hand into picking buckets or boxes, are then transported to a centralized packinghouse where the fruit is further processed. Optimal storage temperatures range between 10 and 13 °C. The recommended storage temperature of tomatoes differs with the cultivar and the maturity of the fruit. Usually tomatoes are sensitive to chilling at temperatures below 10 °C if held for longer than 2 weeks, below 10 °C if held for longer than 2 weeks, or at 5 °C for longer than 6-8 days. Whole tomatoes are generally not waxed or washed before packaging. Production from soil-based systems may however be washed to remove dust, surface dried, sized and packed. In the case of products destined for the fresh-cut market, the products are washed prior to cutting. Fresh and minimally processed tomatoes are normally not subjected to physical interventions that will eliminate the occurrence of *Salmonella* and Norovirus.

For the identification of the main risk factors for *Salmonella* and Norovirus in tomatoes, including agricultural production systems, origin and further processing, the BIOHAZ Panel concluded that the risk factors for the contamination of tomatoes with *Salmonella* are poorly documented in the EU with limited available data in the literature but are likely to include the following, based on what is known for other pathogenic bacteria or other types of fresh produce: (1) environmental factors, in particular proximity to animal rearing operations and climatic conditions that increase the transfer of pathogens from animal reservoirs to the tomato plants; (2) contact with animal reservoirs (domestic or wild life) gaining access to tomato growing areas; (3) use of untreated or insufficiently treated organic amendments; (4) use of contaminated water either for irrigation or for application of agricultural chemicals such as pesticides, and (5) contamination or cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

The risk factors for the contamination of tomatoes with Norovirus in the EU are also poorly documented in the literature with limited available data but are likely to include the following, based on what is known for other pathogens or other fresh produce: (1) environmental factors, in particular climatic conditions (e.g. heavy rainfall) that increase the transfer of Norovirus from sewage or sewage effluents to irrigation water sources or to tomato growing areas; (2) use of sewage contaminated water either for irrigation or for application of agricultural chemicals such as pesticides, and (3) contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

The ability of *Salmonella* to survive on or in tomatoes is cultivar dependent and the growth stage of the plant also represents an important factor for internalization of *Salmonella* through the root system, suggesting that plants are more susceptible to internalization immediately after transplantation. Several studies reported that *Salmonella* internalization can occur through the porous tissues of the stem scar and this internalization usually occurs within the core tissue segments immediately underneath the stem scars. Even if *Salmonella* is located on the tomato surface, it can be transferred to the flesh during further handling or cutting and can survive or even grow, as some *Salmonella* serovars have demonstrated the ability to survive on different parts of the tomato plant. No information is available on the potential for Norovirus to internalise within, or survive on, tomatoes. For both *Salmonella* and Norovirus, processes at primary production which wet tomatoes represent the highest risk of contamination, and these include spray application of agricultural chemicals such as fungicides and, if applied, the use of overhead irrigation.

During minimal processing, contamination or cross-contamination via equipment, water and via food handlers are the main risk factors for fresh or cut tomatoes for *Salmonella*. For *Salmonella*, the risk of cross-contamination during washing (whenever applied), is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

Salmonella has been shown to persist on the surface of intact tomatoes. It is likely that Norovirus would be able to persist through the procedures involved in minimal processing of fresh tomatoes, although no direct information is available.

At distribution, retail, catering and in domestic and commercial environments, cross-contamination of items, in particular via direct or indirect contact between raw contaminated food and tomatoes, are the main risk factors for *Salmonella.* These cross-contamination risks include the environments of salad bars. At distribution, retail, catering and in domestic or commercial environments, the Norovirus-infected food handler is the main risk factor. This can be direct or indirect via poor hand hygiene or food contact surfaces that have been subjected to cross-contamination. These contamination and cross-contamination risks include the environments of salad bars.

Salmonella will grow on sliced, diced, cut tomatoes and some tomato products provided these are stored at temperatures which will allow growth. There is also evidence for the survival of *Salmonella* in tomato juice.

For the recommendation of possible specific mitigation options and the assessment of their effectiveness and efficiency to reduce the risk for humans posed by *Salmonella* and Norovirus in tomatoes, the BIOHAZ Panel concluded that appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing tomatoes. These food safety management systems should be implemented along the farm to fork continuum and will be applicable to the control of a range of microbiological hazards.

As *Salmonella* has reservoirs in domestic as well as in wild animals, birds and humans, the main mitigation options for reducing the risk of contamination of tomatoes are to prevent direct contact with faeces as well as indirect contact through slurries, organic amendments and contaminated soil, water,

equipment or food contact surfaces. Apart from avoiding the use of sewage-contaminated water at all stages of the supply chain, the main mitigation options for reducing the risk of Norovirus contamination on tomatoes are scrupulous adherence to hand hygiene by food handlers at all stages of the supply chain. Persons with symptoms of gastroenteritis, including vomiting, should be excluded from working in food production until their symptoms have subsided.

Attention should be paid to the selection of the water source for irrigation, agricultural chemical application (e.g. pesticides and fungicides) and in particular avoiding the use or the ingress of sewage contaminated water. Compliance with existing prerequisite programmes such as Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP), and with recommended Codes of Practices and guidance such as the relevant Codex guidelines, will assist *Salmonella* and Norovirus risk mitigation strategies. Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, intervention strategies should be applied to restrict growers from using this land for primary production until the hazards have been addressed. Each farm environment (including open field or greenhouse production) should be evaluated independently as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of foodborne pathogens in or near tomato growing areas.

Among the potential interventions, both efficient drainage systems that take up excess overflows and water treatment (at primary production and processing) are needed to prevent the additional dissemination of contaminated water. Since *E. coli* is an indicator micro-organism for faecal contamination in irrigation and process water, growers should arrange for periodic testing to be carried out to inform preventive measures.

All persons involved in the handling of tomatoes should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices. Consumers should be advised on how to handle, prepare, and store tomatoes safely to avoid cross-contamination with foodborne pathogens from various sources (e.g. hands, sinks, cutting boards, utensils, raw meats).

For the recommendation, if considered relevant, of microbiological criteria for *Salmonella* and Norovirus in tomatoes throughout the production chain, the BIOHAZ Panel concluded that epidemiological data from the EU have identified one salmonellosis outbreak and one Norovirus outbreak associated with tomato consumption between 2007 and 2012. There is no routine or regular monitoring of tomatoes for the presence of *Salmonella* in EU Member States and there is very limited data on the occurrence of *Salmonella* in/on tomatoes in Europe although there are some studies available in the peer-reviewed world literature. There is no routine or regular monitoring of tomatoes for the presence of Norovirus in EU Member States and there are very limited data on the occurrence of Norovirus in/on tomatoes in the peer-reviewed world literature. There are limited studies which have enumerated *E. coli* in/on tomatoes and these relate to fresh tomatoes produced outside the EU. There are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination for *Salmonella,* Norovirus and *E. coli.*

The current legal framework does not include microbiological criteria applicable at the primary production stage. The current lack of data does not allow the proposal of a Hygiene Criterion for *E. coli* at primary production of tomatoes.

There is insufficient information available on the occurrence and levels of *E. coli* in pre-cut, mashed and other minimally processed tomatoes and therefore the suitability of this criterion cannot be assessed. For this reason it is therefore not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion for these products. Using *E. coli* as an indicator for verification of GMP and food safety management systems (including HACCP) might be useful for tomatoes in individual

processing premises e.g. during food safety management audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

The Food Safety Criterion in Regulation (EC) No 2073/2005 requires an absence of *Salmonella* in 25 g samples (n = 5; c = 0) of ready-to-eat pre-cut tomatoes as well as in unpasteurised tomato juice placed on the market during their shelf life. A Food Safety Criterion for *Salmonella* in whole tomatoes could be considered as a tool to communicate to producers and processors that *Salmonella* should not be present in the product. Testing of whole tomatoes for *Salmonella* could be limited to instances where other factors indicate breaches in GAP, GHP, GMP or HACCP programmes.

Although Noroviruses have been detected in tomatoes, occurrence studies are limited, and quantitative data on viral load are scarce. For Norovirus, there is very limited occurrence data in the world wide literature and only one outbreak was reported in the EU between 2007 and 2012, due to a (vomiting) food handler during buffet preparation in catering, thus it is currently not possible to provide a risk base for establishing a Food Safety Criterion for these foods. The methodology used for detection and quantification of Norovirus in tomatoes does not discriminate between infectious and non-infectious Norovirus and therefore presents a greater level of uncertainty than that for most bacteria since it may overestimate or underestimate the risk.

The BIOHAZ Panel also recommended that: (1) more detailed categorization of food of non-animal origin should be introduced to allow disaggregation of the currently reported data collected via EFSA's zoonoses database on occurrence and enumeration of foodborne pathogens; (2) ISO technical specifications for Norovirus detection and quantification on tomatoes should be further refined with regard to sampling, sample preparation, limit of detection, quantitative accuracy and interpretation of results; (3) there should be implementation and evaluation of procedures such as sanitary surveys, training, observational audits and other methods to verify agricultural and hygiene practices for tomatoes; (4) further data should be collected to evaluate the suitability of *E. coli* criteria at both primary production and during minimal processing of tomatoes; (5) risk assessment studies are needed to inform the level of hazard control that should be achieved at different stages of tomato production and minimal processing. Such studies should be supported by targeted surveys on the occurrence of *Salmonella* and Norovirus in tomatoes at specific steps in the food chain to identify the level of hazard control and efficacy of application of food safety management systems, including GAP, GHP, GMP and HACCP, that has been achieved at different stages of production systems; (6) research should be undertaken with the aim of (i) developing infectivity assays for Norovirus and (ii) investigating survival of foodborne pathogens including internalisation in tomatoes during crop production at natural exposure levels and (7) further data should be collected to evaluate the suitability of bacterial or viral indicators for monitoring Norovirus and other relevant microbiological hazards in tomatoes and in tomato production and processing environments. Monitoring for suitable indicators could include water used in primary production, and also applied to food handlers' hands, and could be performed during audit to verify compliance with good practice.

TABLE OF CONTENTS

BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

In May 2011 a major outbreak of Shiga toxin-producing *Escherichia coli* (STEC[4]) O104:H4 occurred in Germany. About 4,000 people were reported ill with symptoms and the outbreak resulted in the death of more than 56 people. Other countries reported a certain number of people becoming ill by the same strain, most of whom had recently visited the region of northern Germany where the outbreak occurred. At the end of June 2011, there was a second cluster in Bordeaux, France, which was caused by the same *Escherichia coli* strain. In both cases, investigations pointed to the direction of sprouted seeds.

According to the 2009 Zoonoses Report[5], the majority of verified outbreaks in the EU were associated with foodstuffs of animal origin. Fruit and vegetables were implicated in 43 (4.4 %) verified outbreaks. These outbreaks were primarily caused by frozen raspberries contaminated with Norovirus.

According to the US Centre for Disease Control and Prevention (CDC) 2008 report on surveillance for food borne disease outbreaks[6], the two main commodities associated with most of the outbreak-related illnesses originating from food of plant origin were fruits-nuts and vine-stalk vegetables. One of the main pathogen-commodity pair responsible for most of the outbreaks was Norovirus in leafy vegetables. The pathogen-commodity pairs responsible for most of the outbreak-related illnesses were *Salmonella* spp. in vine-stalk vegetables and *Salmonella* spp. in fruits-nuts. In addition, as recently as September 2011, a multistate outbreak of listeriosis linked to cantaloupe melons caused 29 deaths in the US.

Regulation (EC) No 852/2004 on the hygiene of foodstuffs[7] lays down general hygiene requirements to be respected by food businesses at all stages of the food chain. All food business operators have to comply with requirements for good hygiene practice in accordance with this Regulation, thus preventing the contamination of food of animal and of plant origin. Establishments other than primary producers and associated activities must implement procedures based on the Hazard Analysis and Critical Control Points (HACCP) principles to monitor effectively the risks.

In addition to the general hygiene rules, several microbiological criteria have been laid down in Regulation (EC) No 2073/2005[8] for food of non-animal origin.

Following the STEC O104:H4 outbreak in Germany and France, the Commission already has asked EFSA for a rapid Opinion on seeds and sprouted seeds. EFSA adopted a Scientific Opinion on the risk posed by STEC and other pathogenic bacteria in seeds and sprouted seeds on 20 October 2011. The current mandate intends to supplement the adopted Opinion.

In view of the above, there is a need to evaluate the need for specific control measures for certain food of non-animal origin, supplementing the general hygiene rules.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is asked to issue scientific Opinions on the public health risk posed by pathogens that may contaminate food of non-animal origin such as fruit, vegetables, juices, seeds, nuts, cereals, mushrooms, algae, herbs and spices and, in particular:

[4] Also known as Verocytotoxin-producing *Escherichia coli* (VTEC).
[5] EFSA Journal 2011;9(3):2090
[6] www.cdc.gov/mmwr/preview/mmwrhtml/mm6035a3.htm?s_cid=mm6035a3_w
[7] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p. 1-54.
[8] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

1. To compare the incidence of foodborne human cases linked to food of non-animal origin and foodborne cases linked to food of animal origin. This ToR should provide an indication of the proportionality between these two groups as regard humans cases and, if possible, human burden.

2. To identify and rank specific food/pathogen combinations most often linked to foodborne human cases originating from food of non-animal origin in the EU.

3. To identify the main risk factors for the specific food/pathogen combinations identified under ToR 2, including agricultural production systems, origin and further processing.

4. To recommend possible specific mitigation options and to assess their effectiveness and efficiency to reduce the risk for humans posed by food/pathogen combinations identified under ToR 2.

5. To recommend, if considered relevant, microbiological criteria for the identified specific food/pathogen combinations throughout the production chain.

The Commission would like an Opinion on the first and second terms of reference by the end of December 2012. The outcome of the first and second terms of reference should be discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other terms of reference. The Commission would like an Opinion on the other terms of reference by the end of 2013.

CLARIFICATIONS OF THE TERMS OF REFERENCE 3 TO 5 OF THE REQUEST ON THE RISK POSED BY PATHOGENS IN FOOD OF NON-ANIMAL ORIGIN

BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION

On 23 January 2012, a request was provided to the European Food Safety Authority (EFSA) to issue scientific Opinions on the public health risk posed by pathogens that may contaminate food of non-animal origin (FoNAO).

The BIOHAZ Panel of EFSA adopted during its meeting on 6 December 2012 an Opinion on the first and second terms of reference, focussing on

- the comparison of the incidence of food-borne human cases linked to FoNAO and food-borne cases linked to food of animal origin;

- identifying and ranking specific food/pathogen combinations most often linked to food-borne human cases originating from FoNAO in the EU.

It was agreed in the original request that the outcome of the first and second terms of reference should be discussed between risk assessors and risk managers in order to decide which food/pathogen combinations should be given priority for the other terms of reference addressing risk factors, mitigation options and possible microbiological criteria.

The first Opinion of EFSA under this request identifies more than 20 food/pathogen combinations in its five top ranking groups. The Opinion also contains a preliminary assessment of risk factors linked to certain examples of FoNAO (e.g. tomatoes, watermelons and lettuce), representing specific production methods for several FoNAO. Several risk factors and mitigation options may be common for several food/pathogen combinations due to similar production methods. It seems therefore opportune to combine the risk assessment of such food/pathogen combinations. When risk factors and mitigation options are identified as more specific to the individual food/pathogen combination, then these should be considered to supplement this approach and added where possible within the

Opinions. Alternatively, it is worth mentioning that a reference could be made if such specific risks have already been addressed in previous Opinions.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is asked, in accordance with article 29 of Regulation (EC) No 178/2002[9], to provide scientific Opinions on the public health risk posed by pathogens on food of non-animal origin as regards risk factors, mitigation options and possible microbiological criteria. When considered more appropriate e.g. because of low prevalence of the pathogen or in view of a broader process control, indicators may be proposed as Process Hygiene Criteria. When addressing mitigation options at primary production, attention should be paid to Article 5(3) of Regulation (EC) No 852/2004[10], which laid down that the application of hazard analysis and critical control pints (HACCP) principles shall only be applied to food business operators after primary production and associated activities[11]. This provision does, however, not exclude proposing microbiological criteria in accordance with terms of reference 5 when considered relevant.

EFSA is requested to provide Opinions in line with the agreed terms of Reference 3 to 5 (EFSA-Q-2012-00237) for the following food/pathogen combinations with a similar production system:

(1) The risk from *Salmonella* and Norovirus in leafy greens eaten raw as salads.
Cutting and mixing before placing on the market should be included as potential risk factor and specific mitigation options proposed if relevant.

(2) The risk from *Salmonella*, *Yersinia*, *Shigella* and Norovirus in bulb and stem vegetables, and carrots.

(3) The risk from *Salmonella* and Norovirus in tomatoes.

(4) The risk from *Salmonella* in melons.

(5) The risk from *Salmonella* and Norovirus in berries.

[9] OJ L 31, 1.2.2002, p.1.
[10] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs.
[11] See guidance at: http://ec.europa.eu/food/food/biosafety/hygienelegislation/guidance_doc_852-2004_en.pdf

ASSESSMENT

1. Introduction

Tomatoes are a fresh food commodity which, as a ready-to-eat food, is widely consumed in the EU as a raw or minimally processed product. This food type is generally free from noxious substances such as poisonous chemicals, toxins and pathogenic organisms, however, the previous EFSA Opinion (EFSA Panel on Biological Hazards (BIOHAZ), 2013), risk ranked the combination of this food category together with *Salmonella* spp. and Norovirus, as the second and fifth most often linked to human cases of infection originating from food of non-animal origin in the EU, respectively.

The main risk factors for contamination by foodborne pathogens, together with their mitigation options, are applicable to many points in the food chain for tomatoes. However, since tomatoes can be eaten raw or minimally processed and often do not include any processing steps or control points which will ensure removal or inactivation of biological hazards, it is particularly important to consider risk factors (and consequentially mitigation options) at the point of production. This property is in common with other foods of non-animal origin which are minimally processed and ready-to-eat, as well as some foods of animal origin (e.g. unpasteurised dairy products, shellfish and meats which are eaten raw).

The approaches used in this Opinion are:

1. To provide a descriptive analysis of the whole production process representative of the main types of tomatoes consumed which considers their agricultural production, growth, harvest, as well as processing, distribution, retail, catering and domestic use. Risk factors for contamination by *Salmonella* spp. and Norovirus will be considered in the context of the agricultural, processing, distribution and retail/catering/domestic environments. In discussions with the EU Commission it was agreed that for all the FoNAO considered in these related Opinions, only minimally processed products will be considered (which includes cutting, washing, peeling, shredding, freezing, mashing and unpasteurized juicing). Products undergoing thermal treatments (including blanching as well as shelf stable juices) are not considered in the scope of these Opinions.

2. To assess specific mitigation options, separate Sections are included relating to *Salmonella* spp. or Norovirus contamination of tomatoes. The assessment of the mitigation options was performed in a qualitative manner similar to that used for the Scientific Opinion on the risk posed by Shiga toxin-producing *Escherichia coli* (STEC) and other pathogenic bacteria in seeds and sprouted seeds (EFSA Panel on Biological Hazards (BIOHAZ), 2011b). It included consideration of generic mitigation options previously identified for leafy greens (EFSA BIOHAZ Panel, 2014a) and berries (EFSA BIOHAZ Panel, 2014b) as well as those specific for tomatoes.

3. Sampling and analytical methods for the detection of *Salmonella* spp. and Norovirus (together with the use of *Escherichia coli* as an indicator organism) in tomatoes were considered as identical to those identified for leafy greens (EFSA BIOHAZ Panel, 2014a). A summary of data on the estimates of occurrence for *Salmonella,* Norovirus and *E. coli* in tomatoes is presented. The relevance of microbiological criteria applicable to production, processing and at retail/catering were considered.

2. Production of tomatoes

2.1. Definition of tomatoes

Tomatoes (*Lycopersicum esculentum* Miller) are the fruit from a small herbaceous plant which belongs to the *Solanaceae* family and grows under warm conditions. Although there are extensive

collections of tomato plant genetic resources (http://documents.plant.wur.nl/cgn/pgr/tomato/default.htm), relatively few cultivars are used for commercial fresh tomato production or processing.

Only the fruit of the plant is consumed and the size, shape and colour vary depending on the cultivar. Fruits shapes vary from round (or spherical type) to flattened or ovoid, and the colour includes orange to red or yellow and the skin may be of uniform or variegated colour. The spherical red-fleshed tomato predominates in the fresh market in the EU, but both red and yellow-fleshed spherical, plum, cherry, grape and mini-pear types are also available. The flavour is slightly acid and sweet at the same time. Tomatoes were defined, in a previous Opinion (EFSA Panel on Biological Hazards (BIOHAZ), 2013), as vegetable fruits and examples of cultivars such as grape, currant, plum and beef tomatoes were included. In tomato production, the development of new cultivars has been in constant evolution. Cultivar innovation is a fundamental factor to fulfill consumer expectations in terms of convenience, freshness, flavour, and quality and the commercial cultivars are constantly changing. Thus, changes in the production of tomato cultivars often differ from one production year to another. As such, tomatoes encompass a wide and continuously changing assortment of cultivars.

Based on plant habit and vigour, cultivated tomato plants are divided into two types: indeterminate, where plants are trained to single stems with the side shoots removed, and used for greenhouse production of tomatoes; and determinate, where all side shoots are left on the plants to terminate in clusters of fruits (Papadopoulos, 1991).

High quality tomatoes have a firm, turgid appearance, uniform and shiny skin, and should be without signs of mechanical injury, shrivelling or disease and decay. Depending on the market and production area, tomatoes are harvested at stages of maturity ranging from physiological maturity (mature-green stage) through to fully-ripe (USDA, 2004). Standard tomato quality is primarily based on having a uniform shape and freedom from growth or handling defects. Size is not a factor in grade quality but may strongly influence commercial quality expectations (Suslow and Cantwell, 2002). Principal causes for post-harvest losses are decay, external damage incurred during harvest and handling before the fruit has matured (USDA, 2004).

2.2. Description of production systems

With respect to production systems, tomatoes produced in Europe are either determinate types (bush tomatoes) harvested in one crop, usually grown in open fields for the processing industry, or indeterminate types which are harvested throughout the growing season, usually for the fresh market. With respect to the type of fruits, for fresh market tomatoes, in addition to spherical, a wide array of ovoid, ribbed, and small cocktail types are also grown but on a smaller scale. Seed companies continue to release new cultivars within these types so there is a high diversity of types of tomato cultivars in Europe.

Within the EU most tomatoes for the fresh market are produced in greenhouses, although differences in the type of production can be observed within the EU. For instance, in Spain, growers mostly cultivate in soil using plastic greenhouses (polytunnels) but some growers are moving to more sophisticated systems such as glass greenhouses with temperature control systems. However, small-scale growers still use open field-cultivation in some countries if climatic conditions allow. In Northern European countries, commercial tomatoes are usually cultivated in greenhouses (glass or plastic polytunnels) on substrates (principally rockwool) with a central hot water heating system, and computerized control of environmental conditions and watering (EFSA Panel on Biological Hazards (BIOHAZ), 2013). A wide range of tomato types are also grown by consumers for personal consumption and using allotments and gardens with open or protected cultivation, although this is outside the scope of this Opinion.

2.2.1. Open field production

Open-field tomatoes are usually cultivated using plastic mulch on raised beds. A raised bed will warm up more quickly in the spring and therefore will enhance earlier growth. Since tomatoes grow poorly

in excessively wet soils, drainage in a raised bed helps prevent waterlogging in low lying areas or in poorly drained soils. However, tomatoes planted on raised beds may also require more irrigation during drought conditions (Kelley and Boyhan, 2006a).

Tomatoes can be produced on a variety of soil types. They grow optimally in deep, medium textured sandy loam or loamy, fertile, well-drained soils. Tomato plants depend on the soil for physical support and anchorage as well as nutrients and water. The degree to which the soil adequately provides these three factors depends upon topography, soil type, structure and management. For tomato production, proper tillage is crucial for adequate soil management and optimal yields. Since root development is severely limited by compacted soil, proper land preparation should eliminate or substantially reduce soil compaction (Kelley and Boyhan, 2006b). In open field production, plastic mulch can be also used to promote early fruiting, reduce competition from weeds, and to conserve moisture and fertilizer. Drip irrigation is used most frequently in conjunction with plastic mulch. Plastic mulch promotes early fruiting by capturing heat, which increases soil temperatures and accelerates growth. Black plastic will prevent the establishment of many in-row weeds. Mulch will reduce fertilizer leaching from tomato beds and will conserve moisture by reducing soil surface evaporation. Furthermore, where fumigants are used, plastic mulch provides a barrier that increases fumigant efficiency. Plastic mulch also keeps fruit cleaner by reducing soil splashing onto the plants. Risks from plant diseases are reduced when using drip irrigation as the foliage stays drier and, again, soil is not splashed onto the plant. However, specialized equipment is required to lay plastic mulch, and the cost of plastic removal and disposal is an additional expense (Kelley, 2006).

2.2.2. Greenhouse production

Tomato production in greenhouses can be carried out using soil or soil-less systems. Soil-cultivated tomatoes in greenhouses use similar techniques to those used for open field cultivation. Scientific and technical advances mean that tomato plants can now be successfully grown without soil. All the various methods and techniques developed for growing plants without soil are collectively called soil-less systems. These methods include a great diversity of processes, from the purely hydroponic, which are based on the supply of water and nutrients only (e.g. nutrient film technique, or NFT), to those based on artificial mixes that contain various proportions of different substrates. In between these extremes lie a great number of soil-less or minimal substrate methods that make use of some sort of growth medium, which is either inert (e.g. rockwool slabs, polyurethane chunks, and perlite) or non-inert (e.g. gravel culture, sand culture, and peat bags) (Papadopoulos, 1991). In the case of organic production, only soil is permitted for cultivation of tomatoes.

Planting tomato seeds directly into the field is not recommended due to the high cost of hybrid seed and the specific conditions required for adequate germination. Most tomatoes are transplanted into fields as 5-6-week old seedlings, which have been grown in greenhouses. As with many vegetable crops, container-grown transplants are preferred over bare root plants. Container grown transplants retain transplant growing medium (soil-substitute) attached to their roots after removal from the container which is usually a flat tray (Kelley and Boyhan, 2006a).

The greenhouse environment has a profound effect on crop productivity and profitability. Parameters such as temperature, light, relative humidity, carbon dioxide, and air movement within the greenhouses can all be controlled. Air temperature is the main greenhouse environmental component influencing vegetative growth, formation of fruit clusters and their development, ripening and quality. The average 24 h temperature is considered to be the key variable responsible for the growth rate of the tomato crop. The higher the average air temperature the faster the growth, although this may not necessarily lead to greater fruit production. A large variation in day-night air temperature is thought to lead to taller plants with a smaller leaf size. Although maximum growth occurs at an average day and night temperature of approximately 25 °C, maximum fruit production is achieved with a night temperature of 18 °C and a day temperature of 20 °C (Papadopoulos, 1991).

It should be noted that greenhouse environments are not completely enclosed systems (Guo et al., 2002b) and as with field grown crops tomatoes, those grown in greenhouses are susceptible to insect

pests and plant diseases (Snyder, 2007). However, while a greenhouse environment is excellent for growing tomatoes (and some other vegetables), it is favourable for propagating insect pests and plant pathogens (Nguyen-the and Carlin, 2000). Due to the higher temperature, higher relative humidity, and lush, green foliage, insects and diseases are constant threats once introduced into a greenhouse (Snyder, 2007). Whether this is also true for foodborne pathogen has not been explicitly studied for tomatoes. However, generally on plant surfaces some foodborne pathogens survived better in more humid environments such as found in green houses or plastic tunnels that in open fields (Brandl and Mandrell, 2002; Dreux et al., 2007). For tomatoes, *Salmonella* introduced into green houses after incidents presumably persisted in this environment (Orozco et al., 2008b) and nutrient solutions artificially contaminated with *Salmonella* has been demonstrated to result in colonization of the young tomato plant (Guo et al., 2002b). For further information on *Salmonella* colonization of plants see Section 3.

Cultivation of commercial tomatoes in greenhouses with a central hot water heating system, and computerized control of environmental conditions is used to produce tomatoes in Northern European countries. Hot water heating systems generally use a propane gas hot water heater, a circulation pump, tubing or pipes and a remote bulb thermostat to maintain a 21-24 °C soil temperature in the root zone. The size of the water heater or boiler depends on the area to be heated and the cropping system used. In the simplest system using a water heater, the thermostat on the tank is set at the desired root zone water temperature. Return water from the loops goes back to the tank to be reheated. Activation of the circulation pump is done with a remote bulb thermostat inserted in the soil or growing bag (Bartok, 2013).

2.2.3. Water sources and irrigation systems

Irrigation is essential to produce consistent yields of high quality tomatoes. Several types of irrigation may be successfully used in producing tomatoes. The most common irrigation systems are drip followed by sprinkler irrigation and the main water sources are surface waters, reservoirs, well water and potable quality water in the case of hydroponics. The microbial monitoring of the water sources is usually carried out once per year for tomatoes intended for the fresh market (Appendix A, Freshfel, 2013). The most critical stages for watering are at transplanting, flowering and fruit development (Harrison, 2006).

Drip irrigation is often used in soil systems particularly when cultivating under plastic mulch. One of the major advantages of drip irrigation is its water use efficiency. Some studies have also shown increased yield with drip irrigation and plastic mulch when compared with sprinkler-irrigated tomatoes. Sprinkler systems with high application uniformity (center pivot, linear move and permanent set) are also used (Harrison, 2006). In many cases, fertilizer can be fed continuously at every watering, with the fertilizer concentration in the solution used as an osmoticum in regulating water availability to the plants. The recommended fertilizer concentration in the irrigation water, usually measured by electrical conductivity, varies according to the environmental conditions.

The water supply can be regulated directly, by adjusting the irrigation conditions, or indirectly, by adjusting the relative humidity in the greenhouse and the electrical conductivity of the irrigation water. Of the different approaches, the regulation of electrical conductivity is the most preferred because of its simplicity, effectiveness and dependability (Papadopoulos, 1991).

Water is also used in water-based chemical treatments, such as the application of pesticides and fungicides. Only pesticides and fungicides that are authorized for use on tomatoes by the prevailing regulatory authorities in both the country of origin and destination markets should be used. Special attention should be given to the microbiological quality of the water to avoid the risk of contamination.

2.2.4. Different types of fertilisation, organic/manure/compost

Fertilizer management is impacted by cultural methods, tillage practices and cropping sequences. A proper nutrient management programme takes into account native soil fertility and residual fertilizer. Fertilizer materials dissolved in water and applied to the soil around plant roots at or just after transplanting are called starter solutions. When proper formulations and rates are applied, they can promote rapid root development and early plant growth (Kelley and Boyhan, 2006b). As previously mentioned, fertilizers can be injected into the irrigation system (fertigation). Fertilization can be done with chemical and/or organic fertilizers. Chemical fertilizers are easy to transport, are used efficiently for growth of the plants and give high yields, but it has been observed that with succeeding crops, the quantity of chemical fertilizers has to be increased because of declining soil fertility. Organic fertilizers including manure and compost from wastes and vegetable residues are sometimes used after transplantation.

2.2.5. Harvesting

Tomatoes should only be harvested when they reach the mature-green stage. If tomatoes are harvested any earlier, the fruit will fail to ripen normally. Since the mature-green state is difficult to judge externally, growers will often take a representative sample of fruit from their fields and cut them open for internal examination. Fresh market tomatoes are usually harvested by hand although harvesting operations vary among growers (Hurst, 2006). Harvested tomatoes are usually placed into picking buckets or boxes. The picking buckets or boxes are then transported to a centralized packinghouse where the fruit is further processed. Pickers carry out preliminary grading to remove decayed fruit from the plants as they harvest in the field. This will prevent transmission of plant diseases to otherwise healthy, sound fruit. Wet tomatoes should never be harvested because surface moisture accumulates field heat in the load and enhances spoilage and plant disease development (Hurst, 2006).

Another alternative is to pack the tomatoes in the field, which includes practices to grade, sort, size, clean, pack or palletize tomatoes into containers for commerce. Field packed tomatoes may not necessarily be cleaned or washed by the producer or processor and they may not be transferred to a packinghouse for further handling prior to distribution. These practices could represent a source of contamination (US-FDA, 2009a).

There continues to be scientific debate as to whether the handling of tomatoes or other foods with bare hands, washed frequently with proper hand washing procedures, leads to less contamination than when using gloves. In Europe, workers for most tomato growers do not use gloves when harvesting tomatoes.

Tomatoes can still be harvested, while still attached to stem tissue (further referred as vine tomatoes) or harvested as a mature stage by detaching them from the stem and sold as loose fruit. In both cases handling before packing is reduced to a minimum to avoid damaging the fruit.

2.2.6. Washing and packaging

Care in handling tomatoes between the time of harvest and shipping to market is important for commercial reasons since about half of the costs associated with tomato production are in the grading, cooling and packing of the product. Bulk bins or boxes of harvested tomatoes are taken from the field to the packinghouse. Whole tomatoes are generally not waxed or washed before packaging. Production from soil-based systems may however be washed to remove dust, surface dried, sized and packed. In the case of products destined for the fresh-cut market, the products are washed prior to cutting (see Section 4).

When washing is applied, tomatoes can be mechanically unloaded in a water dump tank (Hurst, 2006). Dump tanks are used for removing dirt, hence water should be frequently changed and disinfectant agents are recommended to maintain the microbial quality of the water. Sanitizers and their concentrations as well as the mode of washing vary depending on the processor and local practices. As an example chlorine at 40-60 mg free chlorine per litre may be used when washing tanks or fluming

are used. However, there are many disinfectant agents commercially available that can be used to maintain the quality of the water such as chlorine dioxide, peracetic acid and hydrogen peroxide among others. Performance for oxidative agents (chlorine or chlorine dioxide) being used as water sanitizer under commercial conditions will vary dependent upon the exact conditions of operation. An increase in turbidity of the water substantially reduced the final oxidation/reduction potential and increased the contact time required for a 5-log inactivation of *S. enterica* in the wash water at any assayed temperature (López-Velasco et al., 2012). The water temperature in the dump tank should be slightly warmer than that of the tomatoes because cooler water temperatures in the dump tank may lead to the tomatoes absorbing water. Spray washing makes use of a jet of clean water to wash the tomatoes. Another alternative is brush spraying which involves the tomatoes being brushed using soft sponges or brushes as they are sprayed with water. Brushing is usually done if the tomatoes are encrusted with dirt and the brushes used should be frequently cleaned and sanitized. In some cases, tomatoes are wiped by hand with a wet or moist cloth. This represents a potential source of cross-contamination between different tomatoes as it involves handling of tomatoes with the same cloth, especially when wet (Sreedharan et al., 2014). Alternatively tomatoes can be sprayed with water on a sorting table and then wiped with a clean piece of cloth (FAO, 2012).

Once tomatoes are washed they are surface dried, pre-graded, colour sorted and sized before being packed (Hurst, 2006). Packaging materials can be classified into two main groups: (1) Bulk packaging materials used for transport, hauling and wholesale marketing, or (2) retail packaging. Regardless of their classification, packaging materials should be convenient to handle, provide protection from mechanical damage and allow air circulation. Retail packaging should, in addition, contain information about the contents (such as volume, source, country of origin, durability), be attractive and provide convenience to the consumer (for example resealable, convenient to carry). Some markets may also specify that packaging materials be recyclable, reusable or biodegradable (FAO, 2012). Fresh tomatoes are usually packed using plastic films and trays for retail packaging. Plastic trays are often used in combination with cartons to keep produce in place and to prevent shifting and abrasion damage (FAO, 2012). Usually, tomatoes are commercially packed in macroperforated films, without modification of the atmosphere.

2.2.7. Cooling and storage

Tomatoes are generally cooled, the optimal temperature ranges from 10 to 13 °C (Appendix A, Freshfel information). However, green tomatoes allow storage at higher temperatures (18 °C) as tomatoes could otherwise get wet when opening the cold stores which might affect their quality. It has been reported that recommended storage temperatures differ with the cultivar and the maturity of the fruit (Suslow and Cantwell, 2002). Most of the tomatoes cultivars are sensitive to chilling at temperatures below 10 °C if held for longer than 2 weeks or at 5 °C for longer than 6-8 days, but the minimum recommended temperature to avoid chilling injury will vary between cultivars. For the commercial production of tomatoes, rapid cooling soon after harvest is recommended. Mature-green tomatoes can be stored up to 14 days prior to ripening at 12.5 °C without reduction of sensory quality and colour development. Decay is likely to increase following storage beyond two weeks at this temperature (Suslow and Cantwell, 2002). In Europe, transport from intensive production in the Southern Europe to the Northern European consumer markets takes on average 1,5 days. Tomatoes can be stored for a maximum of 2-3 weeks, although the use of ethylene inhibitors may however be used to prolong the shelf life even further (Appendix A, Freshfel information). Ethylene (100 ppm) can be used to ripen tomatoes. Good air circulation must be maintained to ensure temperature uniformity within the ripening room and to prevent the accumulation of CO_2 as levels above 1 % retards the action of ethylene in stimulating ripening. The duration of ethylene treatment is typically 24-72 hours (Suslow and Cantwell, 2002).

It has been shown that extended storage can be achieved by using controlled atmospheres, although this is rarely used in commercial settings. Low O_2 levels (3-5 %) delays ripening and inhibits the development of surface and stem-scar fungal disease without impacting on the sensory quality for consumers. Storage times of up to 6 weeks have been reported for tomatoes using 3 % O_2 and

0-3 % CO_2 and the remaining N_2 (Suslow and Cantwell, 2002). However, elevated CO_2 above 3-5 % is not tolerated by most cultivars and will cause injury while low O_2 (1 %) will cause off-flavours, objectionable odours, and other defects, such as internal browning (Suslow and Cantwell, 2002).

High relative humidity (80-90 %) is essential to maximize post-harvest quality and prevent water loss (desiccation). However, extended periods of higher humidity (> 90 %) or condensation may encourage the growth of stem-scar and surface moulds (Suslow and Cantwell, 2002). On the other hand, lower relative humidity may lead to drying out of the stem.

Fresh and minimally processed tomatoes are normally not subjected to physical interventions that will eliminate the occurrence of *Salmonella* and Norovirus.

2.3. Description of EU tomatoes sector

From 2003 to 2012, EU tomato production for the fresh market was between 6 to 7 million MT per annum. From 2007 to 2012 EU tomato production for both the fresh and processed market was 15 to 19 million MT per annum (Appendix B, Table 4, Eurostat).

If production for both the fresh and processed market are considered then in 2012 the five main producers were Italy (33 %), Spain (26 %), Portugal (9 %), Greece (6 %) and the Netherlands (5 %) accounting for 79 % of production (Appendix B, Table 4, Eurostat). Imports from outside the EU amounted to 2.9 % of EU production with the main sources being Morocco, Turkey and Israel (Appendix B, Table 4, Eurostat).

3. Risk factors for microbiological contamination during agricultural production

Production practices, growth conditions and the location of the edible part during growth (soil, soil surface, aerial part) in combination with intrinsic, extrinsic, harvesting and processing factors will affect the microbial status of tomatoes at the time of consumption in the same way as outlined for leafy greens (EFSA BIOHAZ Panel, 2014a). The variability in the production systems and associated environments of tomato production can lead to a wide range of inputs that are potential sources of microbial food safety hazards. Sources of contamination will similarly vary considerably from one type of crop production to another and from one particular setting/context to another, even for the same crop. The following Sections are intended to identify and characterize potential risk factors for contamination of tomatoes in addition to those previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a).

Tomatoes are pulpy fruits with high moisture content and, in most cases, a soft skin, which makes them susceptible to physical damage that accelerates their deterioration by increasing water loss and provides conditions which can increase contamination during production, harvest and transport. Physical damage to tomatoes may occur during harvesting as well as by the action of various pests (rodents, insects, birds and wild mammals) and can lead to increased microbial spoilage and the potential transmission of foodborne pathogens. Tomatoes have been implicated in one outbreak of salmonellosis in Europe between 2007 and 2011 (EFSA Panel on Biological Hazards (BIOHAZ), 2013). In general, the mechanisms for contamination of tomato in the field are largely unknown (Cevallos-Cevallos et al., 2012b). Potential sources for *Salmonella* in agricultural fields outside the EU were reported to include insufficiently composted manure (Termorshuizen et al., 2003), irrigation and run-off water (Dunlop et al., 1952), and excrement of wild animals (Duffy et al., 2004; Simental et al., 2007). In the US, post-harvest contamination has been implicated in several outbreaks as a result of contamination during packing or food preparation. However tomato-associated *Salmonella* outbreaks in North America have also been associated with contamination during the pre-harvest stage including via contaminated water sources used to irrigate and wash tomato crops (CDC, 2005; Hanning et al., 2009; Micallef et al., 2012).

Norovirus has the potential to produce large foodborne outbreaks as illustrated by an outbreak amongst over 400 office workers in Sweden in 2007 where epidemiological information identified

sliced tomatoes served both with a salad buffet and with hamburgers as associated with infection (Zomer et al., 2010).

Risk factors presented below are mostly deduced from those presented for leafy greens in a previous Opinion (EFSA BIOHAZ Panel, 2014a) but may not be supported by direct epidemiological or experimental evidence, unless specified in the relevant Section.

3.1. Environmental factors

As with leafy green vegetables (EFSA BIOHAZ Panel, 2014a), environmental factors refer to the specific conditions of the primary production area, climate, type of crop, which might have an impact on microbial contamination of tomatoes and the persistence of foodborne pathogens in produce fields. Environmental factors, together with farm management practices can have a profound effect on the persistence of enteric micro-organisms under field conditions and the susceptibility of crops to them (Gutierrez-Rodriguez et al., 2012; Park et al., 2013). Studies on airborne transmission of *Salmonella* are very limited and have mainly been carried out in and around poultry and swine facilities (Kwon et al., 2000; Harbaugh et al., 2006). However, little is known about the formation of *Salmonella* aerosols and whether or not these can lead to contamination of tomato plants in the field.

3.1.1. Factors linked to the adherence, survival and internalisation of pathogens with tomatoes

It has been reported that certain *Salmonella* serovars have adapted to persist on or within intact tomatoes (Shi et al., 2007). This hypothesis is supported by Guo et al. (2001) who evaluated the interaction of five different *Salmonella enterica* serovars (Enteritidis, Hartford, Montevideo, Michigan and Poona) with growing tomato plants. These authors inoculated the flowers of the tomato plants with the serovar cocktail and the fruit was screened for the presence of *Salmonella*. Serovar Montevideo was the most persistent followed by the serovar Poona, which could be recovered on the tomato fruit from inoculated flowers 49 days after inoculation (Guo et al., 2001). However, other *Salmonella* serovars were less frequently recovered.

Regarding internalization during pre-harvest, Zheng et al. (2013) demonstrated that both infested soil and contaminated blossoms can lead to low internal levels of fruit contamination with *Salmonella*. However, as previously mentioned, the ability of *Salmonella* to survive on or in tomatoes is cultivar dependent and the growth stage of the plant also represents an important factor for internalization of *Salmonella* through the root system suggesting that plants are more susceptible to internalization immediately after transplantation (Zheng et al., 2013).

For post-harvest tomatoes, *Salmonella enterica* serovar Montevideo was the most persistent serovar on post-harvest tomatoes stored in contact with inoculated soil and surface-inoculated tomatoes, followed by *Salmonella* Poona and *Salmonella* Michigan (Guo et al., 2002a). When different *Salmonella* serovars (Dublin, Enteritidis, Hadar, Infantis, Senftenberg and Typhimurium) were inoculated individually onto unripened (green) tomato fruit, all of the *Salmonella* serovars could persist and grow when maintained at 15 or 25 °C at a RH of 75 or 95 %. In general, *Salmonella* growth after internal (tomatoes inoculated under vacuum to facilitate internalization) and external inoculation in tomatoes was promoted at high incubation temperature (25 °C) and high relative humidity (95 %), although this was serovar dependent (Shi et al., 2007).

Several studies reported that *Salmonella* internalization can occur through the porous tissues of the stem scar and this internalization usually occurs within the core tissue segments immediately underneath the stem scars (Zhuang et al., 1995; Ibarra-Sanchez et al., 2004; Xia et al., 2012). Even if *Salmonella* is located on the tomato surface, these foodborne pathogens can be transferred to the flesh during further handling or cutting (Lin and Wei, 1997) and can survive or even grow, as *Salmonella* serovars demonstrated a great ability to survive on different parts of the tomato plant (Zheng et al., 2013). Zhuang et al. (1995) highlighted that internalization of *Salmonella* was higher in tomatoes tempered at 25 °C followed by dipping in a *Salmonella* suspension at 10 °C as compared with

tomatoes dipped at 25 or 37 °C, suggesting that washing of tomatoes should be carried out in water at a temperature higher than the temperature of the tomatoes. However, Xia et al. (2012) evaluated the effects of tomato cultivar, temperature differential and post-stem removal time on internalization of *Salmonella enterica* serovar Thompson and concluded that cultivar and post-stem removal time by a range of interactions affected the occurrence of *Salmonella* internalisation, while temperature differential had no effect.

The capacity for human Norovirus to persist in an infectious state on the surface of tomatoes is not known precisely, due to the inability to culture the virus in an infectivity assay, and no studies have been reported which have used a surrogate virus. No information is available on the potential for Norovirus to internalise within tomatoes. Only one reported study was identified which observed an enteric virus internalising within tomato plants: Oron et al. (1995) recovered poliovirus from leaves (but not in the fruit) after growth in soil irrigated with poliovirus-contaminated water at levels of 10^3 to 10^4 PFU/ml.

3.1.2. Conditions in the field and adjacent land

The conditions at the growing field as well as in adjacent land were identified as playing a vital role in the microbial safety of leafy greens (EFSA BIOHAZ Panel, 2014a) and risk factors previously identified are applicable to tomatoes. Risk factors for contamination with foodborne pathogens include contact of tomato with airborne contaminants as well as those from the soil, animal droppings, soil amendments (including natural fertilizers) or direct contact with irrigation water. The risks are reduced when contact with the soil is minimized (e.g. by the use of a mulch or biodegradable material) and this is the case for soil-less production, where the contact between tomato and soil is avoided. However, the use of plastic mulch has been proved to enhance dispersal during rainfall of *Salmonella* compared to soil, while organic mulch reduced dispersal compared with plastic (Cevallos-Cevallos et al., 2012a). In contrast, for field production some tomatoes can have contact with soil directly during growth and/or harvesting. The use of clean boxes and/or plastic material to collect harvested tomatoes also reduced contact with soil.

Bird droppings and airborne contaminants (birds nesting around the growth and packing area, nearby livestock, poultry areas or manure storage or treatment facilities, etc.) may also pose a risk of contaminating tomatoes. Risks are also associated with runoff and flooding particularly where adjacent land use is associated with contamination from human or animal excreta.

3.1.3. Climatic conditions

The effects of climatic conditions on the contamination sources and pathways of foodborne pathogens onto leafy greens during the pre-harvest phase was previously outlined (EFSA BIOHAZ Panel, 2014a) and these risk factors are also applicable to tomatoes. Linking climatic conditions with *Salmonella* survival and growth on tomatoes is very challenging. Very few research studies have evaluated the impact of seasonality on the proliferation of *Salmonella* in fresh produce. Marvasi et al. (2013) found that the driest and sunniest seasons were the most conducive to post harvest proliferation of *Salmonella* and tomatoes. However, this study only identified an indirect effect of the climatic conditions as the seasonal effects were only evaluated on the post-harvest proliferation of *Salmonella*. Survival of *Salmonella* on tomato has been previously linked to low levels of moisture and relative humidity (Rathinasabapathi, 2004). Heavy rains may increase the exposure of tomatoes to foodborne pathogens if soil contaminated with pathogens splashes onto fruit surfaces as well as causing contamination through flooding particularly where floodwaters come into direct contact with tomatoes (Orozco et al., 2008b). Plastic mulch prevents direct contact of tomato fruits with foodborne pathogen-contaminated soil (Guo et al., 2002a) but has the potential to enhance splash dispersal by rain or irrigation water. Cevallos-Cevallos et al. (2012a) demonstrated that *Salmonella* may be dispersed by rain to contaminate tomato plants in the field, especially during rain showers of 10 minutes or more and when plastic mulch is used. They concluded that this was probably due, in part, to the different moisture levels on the tomato surface as both plastic and organic mulch stayed wet for at least 24 h after the rain, whereas soil dried within this time. Guo et al. (2002a) reported survival of *Salmonella*

for at least 45 days on inoculated moist soil, suggesting moisture as a major factor affecting the survival of *Salmonella* in agricultural fields. Furthermore, it was also demonstrated that rain may lead to airborne *Salmonella* which may lead to contamination of tomato fruit (Cevallos-Cevallos et al., 2012b).

3.1.4. Contact with animal reservoirs

Domestic animals (cattle, sheep, horses, chickens, dogs and cats) as well as wild animals (e.g. frogs, lizards, snakes, rodents, foxes, deer, badgers or wild boar) and birds can contaminate leafy green crops with their faeces if they are present in growing areas (EFSA BIOHAZ Panel, 2014a) and risk factors previously identified are applicable to tomatoes. While domestic animals may be separated from growing operations for tomatoes, it can be more difficult to control access by wild animals and birds. Wild and domestic animal species (as well as humans) represent risk factors for contamination of tomatoes with foodborne pathogens when they are present in the production environment and present a risk both from direct contamination of the crop and soil as well as from contamination of surface water sources and other (particularly water) inputs. Bird droppings and airborne contaminants (birds nesting around the packing area, nearby livestock, poultry areas or manure storage or treatment facilities, etc.) may also pose a risk of contaminating tomatoes. Greene et al. (2008) suggested that in a salmonellosis outbreak which occurred in 2005, the most feasible source of contamination for tomatoes was likely to be pond water contaminated with faeces of wild animals such as birds, reptiles or amphibians. Gruszynski et al. (2014) evaluated wildlife as a potential source of *Salmonella enterica* serovar Newport contamination of tomatoes that caused several multi-state outbreaks (Orozco et al., 2008b). Gulls were identified as a potential vehicle for *S.* Newport contamination of tomatoes grown on the Eastern Shore of Virginia (US) (Gruszynski et al., 2014). Domestic and wild animals should therefore be excluded from the tomato production areas, to the extent possible, using appropriate biological, cultivation, physical and chemical pest control methods.

3.2. Organic amendments (manure, slurries, composts, wastewater treatment sludge and sewage)

The use of untreated manure and liquid manure are risk factors for *Salmonella* contamination of tomatoes. The persistence of foodborne pathogens (including *Salmonella*) has been highlighted previously for leafy greens (EFSA BIOHAZ Panel, 2014a). Tomatoes may be contaminated through contact with soil amendments containing human pathogens applied after plant emergence. Although contact between soil and tomato is reduced in the current production methods, these are mostly based on protected crops using greenhouses and hydroponic systems. The use of organic amendments in the soil represents a potential source of contamination, if not properly treated. Guo et al. (2002a) demonstrated that *Salmonella* survived for at least 45 days in contaminated moist soil, which was able to contaminate tomatoes in contact with the soil. A recent study carried out to identify routes of transmission for *Salmonella* on tomato farms highlighted soil as one of the possible source of *Salmonella* (Micallef et al., 2012). Appropriate management of manure and compost are also important as tomatoes could become contaminated from inadequately composted manure if used during cultivation.

There is a risk of contamination of tomatoes with Norovirus at pre-harvest if the crop is spray-irrigated, or pesticides are applied in sewage-contaminated water.

3.3. Water use during production (irrigation, pesticides and fertilizers, washing)

Clean water should only be used for tomato production and, as with leafy greens (EFSA BIOHAZ Panel, 2014a), water from contaminated sources represents a major risk factor for contamination with foodborne pathogens. Risks can be minimised by growers identifying the sources of water used on the farm (municipality, re-used, irrigation water, reclaimed wastewater, discharge water from aquaculture, well, open canal, reservoir, rivers, lakes, farm ponds, etc.). The risk posed by water should be minimised by assessing the microbial quality of the sources of water used on the farm for the presence of foodborne pathogens which should include a documented check detailing the potential for microbial contamination from all possible human and/or animal faecal sources of contamination (e.g. from

animals, human habitation, leaks from sanitary facilities in the field, sewage treatment, manure and composting operations) and the water's suitability for its intended use. In the case of identified contamination sources of the water used on the farm, corrective actions should be taken to minimize the risk. The effectiveness of corrective actions should be verified.

Investigations of *Salmonella* outbreaks due to contaminated tomatoes in the US has highlighted contaminated irrigation water and contaminated wash water as potential sources (Hanning et al., 2009). Follow-up investigations after an outbreak of salmonellosis associated with tomatoes which occurred in 2005 found that the pond water used for irrigation was the source of contamination and investigators speculated that wild birds, reptiles or amphibians were a likely source (Greene et al., 2008). In a baseline study where samples from groundwater, irrigation pond water, pond sediment and irrigation ditch water of a tomato farms were analysed, results indicated irrigation water as a possible reservoir of *Salmonella* on tomato farms and irrigation ditches as temporary habitats for *Salmonella* (Micallef et al., 2012). However, irrigation with contaminated water does not always results in contamination of tomatoes. Jablasone et al. (2004) demonstrated that water contaminated with *Salmonella* applied directly into the soil did not result in the transmission of *Salmonella* to tomatoes. In addition to the quality of the irrigation water, irrigation practices in terms of amount of water may also affect the susceptibility of tomatoes to post-harvest *Salmonella* growth inside tomatoes. Marvasi et al. (2013) reported that artificial soaking of tomato pericarp tissues in water caused a 10-fold increase of inoculated *Salmonella* growth. However, these authors could not reproduce such an increase of *Salmonella* growth by over irrigating field grown tomatoes.

Harvested tomatoes are taken from the field to the packing house, where the fruit is sometimes washed (See Section 2.2.6 of this Opinion). In 1993, a US multistate outbreak of *S.* Montevideo was associated with washed tomatoes that had been dumped into a warmed, chlorinated water bath (Zhuang et al., 1995; Hedberg et al., 1999). Dip washing of tomatoes may result in the diffusion of water to the interior of the fruit (Ibarra-Sanchez et al., 2004). A temperature differential between water in the washing tank and the tomatoes (i.e. tomatoes warmer than water) has been highlighted as a risk factor for internalization of *Salmonella* (see Section 3.1.1), but the above cited studies show that inversion of this differential (water warmer than tomatoes) and chlorination is presumably not sufficient to avoid *Salmonella* cross-contamination of the tomato fruits.

The differential between tomato dump tank temperature and the internal tomato pulp temperature has been considered a critical factor that might favour internalization of *Salmonella* as part of ingress of water during packinghouse operations (Zhuang et al., 1995) and food safety guidelines have recommended the maintenance of at least a 5.6 °C positive temperature differential (Suslow, 2004; US-FDA, 2009a; Xia et al., 2012). However, Xia et al. (2012) have recently demonstrated that the temperature differential showed no significant effect on the frequency of *S. enterica* internalization and a limited effect on the populations of internalized cells. These authors conclude that maintaining sufficient sanitizer levels in the tomato dump tank is critical to avoid pathogen internalization because, once internalized, tomato tissues sequester bacteria and these become difficult to remove or inactivate.

Contact with faecally contaminated irrigation water may expose tomatoes to contamination with pathogens such as *Salmonella* or Norovirus if there is sewage contamination, particularly if the water is delivered by spray irrigation, e.g. by overhead sprinklers. Norovirus is capable of survival in pesticide-containing water (Verhaelen et al., 2013), and spraying such water onto the crop might result in Norovirus-contaminated tomatoes.

As previously stated in Section 5.2 of the Scientific Opinion of the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards (BIOHAZ), 2011a) it is important to estimate the concentration of Norovirus and *Salmonella* on tomatoes after over-head irrigation, and to assess the volume of retained water on such products as a function of the duration of irrigation. The extent of pathogen adherence on to fruits such as tomatoes also needs to be determined.

3.4. Equipment

Risks associated with contamination from equipment and handling were previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a), which can occur at any point in the farm-to-plate continuum, and these risks are equally applicable to tomato production. Tomato damage, however, is an additional risk factor for foodborne pathogen contamination during harvest, and sharp edged or poorly designed storage containers are risk factors that may contribute to tomato damage. Cross-contamination of surfaces by workers handling contaminated produce is possible. Harvest equipment (knives, pruners, machetes and other cutting equipment), together with transport containers and any farm machinery (gondolas, trailers or wagons), which comes into contact with tomato, represent risk factors for contamination as well as surfaces which may have indirect contact with the fruit such as workers shoes, equipment wheels and packing materials which may have contact with the floor (Orozco et al., 2008b).

3.5. Worker health and hygiene, worker training

People working with leafy greens eaten raw as salads can transfer micro-organisms of major public health concern to plants by direct contact (EFSA BIOHAZ Panel, 2014a) and this risk is also important for tomatoes, particularly as they are often consumed whole and do not have outer parts of the plant which are removed. Poor hygienic practices by agricultural workers in the field (including leakage from portable toilets to fields and in-field defecation) has also been identified as potential source of contamination (Suslow et al., 2003) and these poor practices as well as deliberate contamination with faecal material will also substantially increase the risk of contaminating tomatoes. Good hygienic practices during pre-harvest, harvest and post-harvest activities are essential. Since tomatoes are seldom, if at all, harvested mechanically, and are therefore handled extensively during harvest, personal hygiene including attention to clothing is critical when manual harvesting.

The health and hygiene of fruit pickers are critical factors for Norovirus contamination particularly since tomatoes are usually not harvested mechanically, and are handled extensively. The shedding of Norovirus by infected persons can generate very high numbers of virus particles (EFSA Panel on Biological Hazards (BIOHAZ), 2012), and poor-compliance with good hygiene by infected handlers is likely to result in tomato contamination via hands. It has been shown experimentally that Norovirus can be transferred from fingertips to the surfaces of whole tomatoes, even when the virus suspension was dried on the fingertip surface (Tuladhar et al., 2013).

Risks of foodborne pathogen contamination can occur due to cross-contamination with micro-organisms associated with harvesting methods and can be via soil or extraneous debris on the fruit during and after harvesting. An analysis of outbreaks linked to fresh produce in the US identified that fruits that had been dropped on the ground or were in contact with the soil represented a factor that could increase the risk of contamination of intact fruits with bacterial pathogens (Sivapalasingam et al., 2004). Poor sorting and selection of tomatoes is a risk factor for contamination, and in order to prevent cross-contaminating healthy tomatoes during harvest, harvest workers should not handle diseased, damaged or fallen fruit in the field. Failure to segregate and remove culled fruit from the field is a risk factor for contamination of healthy fruit, which will further attract pests and encourage spoilage.

3.6. Conclusion

The risk factors for the contamination of tomatoes with *Salmonella* are poorly documented in the EU with limited available data in the literature but are likely to include the following, based on what is known for other pathogenic bacteria or other types of fresh produce:

- environmental factors, in particular proximity to animal rearing operations and climatic conditions that increase the transfer to pathogens from animal reservoirs to the tomato plants;
- contact with animal reservoir (domestic or wild life) gaining access to tomato growing areas;

- use of untreated or insufficiently treated organic amendments;
- use of contaminated water either for irrigation or for application of agricultural chemicals such as pesticides and
- contamination or cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

The risk factors for the contamination of tomatoes with Norovirus in the EU are also poorly documented in the literature with limited available data but are likely to include the following, based on what is known for other pathogens or other fresh produce:

- environmental factors, in particular climatic conditions (e.g. heavy rainfall) that increase the transfer of Norovirus from sewage or sewage effluents to irrigation water sources or to tomato growing areas;
- use of sewage contaminated water either for irrigation or for application of agricultural chemicals such as pesticides and
- contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

The ability of *Salmonella* to survive on or in tomatoes is cultivar dependent and the growth stage of the plant also represents an important factor for internalization of *Salmonella* through the root system, suggesting that plants are more susceptible to internalization immediately after transplantation.

Several studies reported that *Salmonella* internalization can occur through the porous tissues of the stem scar and this internalization usually occurs within the core tissue segments immediately underneath the stem scars.

Even if *Salmonella* is located on the tomato surface, it can be transferred to the flesh during further handling or cutting and can survive or even grow, as some *Salmonella* serovars have demonstrated the ability to survive on different parts of the tomato plant.

No information is available on the potential for Norovirus to internalise within or survive on tomatoes.

For both *Salmonella* and Norovirus, processes at primary production which wet tomatoes and tomato plants represent the highest risk of contamination with both pathogens, and these include spray application of agricultural chemicals such as fungicides and, if applied, the use of overhead irrigation.

4. Description of processing methods for tomatoes

Tomatoes may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, stem removal, cutting, packaging and storage. Other types of processing (e.g. freezing, mashing and commercial juicing without pasteurisation etc) rarely occur outside retail and catering and are not further considered in this Opinion. Unpasteurized juicing however may take place at retail or catering and is considered in Section 6. Tomatoes may be also subject to cooking, drying, bottling, canning and other processes, but these are outside the scope of this Opinion.

Tomatoes can be subjected to minimal processing once ripe. During processing, tomatoes are delivered to the processing plant and transferred to flumes through manual, mechanical or hydraulic means. Thus, the first step is the reception and inspection of the raw material to assure the rejection of inferior quality product. The temperature in the processing plant is usually between 5 to 10 °C. Tomatoes are then conveyed through flumes to the washing area. Washing can be achieved by simply spraying with potable water, although it generally involves the immersion of the product in chilled water at 1 to 10 °C. Disinfectants, such as chlorine, are sometimes added to the water in baths or wash-

tanks to help maintain the quality of the potable water depending upon national policies for their use and approval for the use of disinfectants. The required free chlorine doses applied to the washing tank will vary depending on the concentration of organic matter in the process water, although a residual concentration of at least 10-20 ppm of free chlorine is recommended.

As with leafy greens (EFSA BIOHAZ Panel, 2014a), the quality of the water used for washing tomatoes is a key consideration. Where tomatoes are washed this will have some effect by reducing the microbiota (including foodborne pathogens) but it may also result in cross-contamination if the microbial quality of the process water is not controlled using a disinfectant treatment. Thus, the main goal of using disinfection agents will be to avoid cross-contamination between different batches of tomatoes. However, washing tomatoes in water for 1 min was shown to result in a 1.2 log CFU/cm^2 reduction of *S. enterica* (Pao et al., 2007). As for leafy greens (EFSA BIOHAZ Panel, 2014a), chlorine derived compounds are the most frequently used disinfectants during washing in commercial facilities to maintain the quality of the process water. In addition, other treatments (e.g. chlorine dioxide, peroxyacetic acid, hydrogen peroxide, electrolized water) have been used on a more experimental basis and are further discussed in Section 12.2.

Whenever disinfectants are used, the last stage before packaging should be the rinsing step, which requires very low doses of disinfection agent to maintain the hygienic quality of the water.

Survival of *Salmonella* is likely to occur on both ambient stored as well as in refrigerated tomato preparations (Allen et al., 2005). Norovirus may be able to persist in an infectious state on tomatoes stored at ambient and at refrigeration temperatures; however, no direct information is available on this.

4.1.1. Cutting, mashing, freezing, unpasteurised juicing

After washing, tomatoes can be subjected to cutting, usually by means of mechanical cutters. The final operation in the processing of fresh-cut tomatoes takes place in the assembly and packaging room. Packing trays usually contain absorption pads to absorb accumulated juice. In the assembly room, after inserting the correct amount of cut product into the trays, the packs are sealed. Polymeric films are used in an effort to maintain product quality, while extending shelf-life (Gil and Selma, 2006). Before sealing, the atmospheres within the packages may be evacuated or flushed with a mixture of gases to more rapidly establish a desirable modified atmosphere (MA). MA containing 3 % O_2 and 3 % CO_2 has been recommended. Proper temperature control during storage and transportation is critical to maintaining visual quality and to delay microbial growth during the shelf life for fresh-cut tomatoes. The marketing temperature recommended for fresh-cut tomatoes is between 0 and 5 °C (Gorny, 2001).

A cold soup usually made with tomatoes known as gazpacho can be produced as well as other products, such as salsa, which require cutting and mashing of this fruit. Although produced in catering and in domestic environments (see Section 6), industrial products of this type are almost always subjected to a pasteurisation treatment. Thus, this is outside the scope of this Opinion as a commercial product.

5. Risk factors for microbiological contamination during processing treatments, including the main processing practices

Ripe tomatoes have an internal pH of 3.4 - 4.7, 94.5 (g/100 g) water content, 0.88 (g/100 g fresh weight) protein, and 2.6 (g/100g fresh weight) sugar content (Carlin, 2007). The surface of intact tomatoes is dry and waxy and *Salmonella enterica* (serovars Agona, Gaminara, Montevideo and Poona) were shown to survive and not significantly decline over 200 hours at 4, 12 and 21 °C (Ma et al., 2010) although about 1 log reduction of *Salmonella enterica* (Poona, Stanley, Baildon and Typhimurium) was detected over 10 days at 4 °C (Obaidat and Frank, 2009).

Processing tomatoes into fresh-cut products may increase the risk of bacterial contamination, persistence or growth of both spoilage organisms as well as potential pathogens, by breaking the natural exterior barrier of the produce. In general, the risk of survival and multiplication of foodborne

pathogens on produce is enhanced once the protective epidermal barrier has been broken. Cut tomatoes, by definition, have been injured through peeling, cutting, or slicing. These same operations can transfer pathogenic micro-organisms, if present, from the surface of the intact fruit to the internal tissues (US-FDA, 2009b). The release of plant cellular fluids when tomatoes are cut provides a nutritive medium in which pathogens, if present, can survive or grow. The pH of tomato pulp varies depending on the cultivar but usually ranges between 3.0 and 4.5, although some cultivars have a pH higher than this. Low-acid food is defined as a food having a pH of more than 4.6, while a high-acid food is defined as a food with a pH value of 4.6 or lower. If the pH of tomato pulp is higher than 4.6, it will allow the growth of micro-organisms, including *Salmonella*. Survival of *Salmonella enterica* (Poona, Stanley, Baildon and Typhimurium) on sliced tomatoes was detected over 10 days at 4 °C, with 0 to 1 log growth at 10 °C, and up to 3 logs growth at 25 °C after 10 days (Obaidat and Frank, 2009). Similar results were reported by Ma et al. (2010) where survival of *Salmonella enterica* (serovars Agona, Gaminara, Montevideo and Poona) was reported on sliced tomatoes over a 200 hour period at 4, with a 2 log increase at 12 °C and a 3 log increase after 24 hours followed by a decline at 21 °C. Similar results were reported by: Asplund and Nurmi (1991) with growth of *S. enterica* serovars Enteritidis, Infantis and Typhimurium on cut tomatoes at 22 and 30 but not 7 °C; Zhuang et al. (1995) reported growth of *S.* Montevideo on chopped tomatoes at 20 and 30 but not at 5 °C; and Weissinger et al. (2000) reported growth of *S.* Baildon on diced Roma tomatoes at 21 and 30 °C.

The degree of handling, common to many fresh-cut processing operations, can provide opportunities for contamination and for spreading contamination through a large volume of product. Some processing practices may lead to infiltration and the microbial contamination of the internal environment of tomatoes. It is essential that processors are familiar with their raw material suppliers, whether the tomatoes have been washed and develop appropriate steps to maintain water quality and minimize the potential for infiltration (North American Tomato Trade Work Group and United Fresh Produce Association, 2008). The processing of fresh tomatoes without proper sanitation procedures in the processing environment increases the potential for cross-contamination of *Salmonella* and, as described above, if not refrigerated may lead to growth of the bacterium (North American Tomato Trade Work Group and United Fresh Produce Association, 2008).

5.1. Environmental factors

Environmental factors refer to the specific conditions of the processing area, which might have an impact on the safety of the tomatoes and have been previously considered for leafy green vegetables (CAC, 2003). The environment of the processing plant may represent a risk for cross-contamination between products. The production environment is likely to be refrigerated which, if the product has not already been refrigerated, should be implemented immediately after harvesting and will prevent the growth of pathogenic bacteria.

5.2. Water sources (washing)

Washing is an important step in the processing of fresh-cut tomatoes. Risk factors previously identified for leafy green (EFSA BIOHAZ Panel, 2014a) are applicable to tomatoes. Additionally, in tomatoes, the differential between tomato dump tank temperature and tomato pulp temperature has been considered a critical factor that might favour internalization of *Salmonella* during washing (Zhuang et al., 1995). However, it has been established that *Salmonella* is able under experimental conditions to internalize in tomato tissue independently of a temperature differential between fruit and wash water (Xia et al., 2012).

For *Salmonella*, this risk of cross-contamination during washing is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

5.3. Equipment

Risks from contamination via process equipment were previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014a). However, as outlined in the previous Section, tomato damage is a risk factor

for foodborne pathogen contamination during production and storage. In an experimental system, spoilage of ripe tomatoes by proteolytic fungi stored at 15 and 25 °C (which simulates damage, for example, during processing) was shown to result in an elevation of the pH of the tomato pulp and allowed a promotion of *Salmonella* growth when inoculated into the mouldy tomato tissue during 10 days observation (Wade and Beuchat, 2003). Therefore poor handling during post-harvest packing are risk factors that may contribute to tomato damage and increased contamination by *Salmonella*. Cross-contamination of surfaces by workers handling contaminated produce is possible.

Equipment such as knives and other cutting equipment used post-harvesting, conveyor belts or utensils used for processing, may act as vehicles for cross-contamination of tomatoes. A study using murine Norovirus as a model demonstrated that knives and graters used in processing contaminated fresh produce items including cucumbers and tomatoes and could become themselves contaminated by the virus and then be able to pass the contamination on to subsequently processed items (Wang et al., 2013).

Cross-contamination of surfaces by workers handling contaminated produce is possible. Stals et al. (2013) demonstrated that Norovirus GII.4 could be transferred from gloves to a stainless steel surface and from that to foodstuffs, and vice versa.

5.4. Worker health and hygiene, worker training

As previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014a) as well as for any other sectors processing ready-to-eat foods, lack of compliance of workers with Good Manufacturing Practices (GMPs) and Good Hygiene Practices (GHPs) and food safety management systems (including HACCP) are a risk factor for tomato processing. This includes adequate training as well as hand washing and toilet facilities which are further considered in Section 12.2.5.

5.5. Conclusion

During minimal processing, contamination or cross-contamination via equipment, water and via food handlers are the main risk factors for fresh or cut tomatoes for *Salmonella*.

For *Salmonella*, the risk of cross-contamination during washing (whenever applied), is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus are not fully defined due to the lack of an infectivity assay.

Salmonella has been shown to persist on the surface of intact tomatoes, and will survive and grow in sliced, diced or cut product at temperatures which will allow growth.

It is likely that Norovirus would be able to persist through the procedures involved in minimal processing of fresh tomatoes, although no direct information is available.

6. Description of the distribution, retail and catering including domestic and commercial environments for tomatoes

In addition to being sold as whole fruit (either loose or packaged as well as separate or on the vine), tomatoes are also sold as a loose cut product in salad bars at both retail and in catering, sometimes allowing for self-selection and service by the consumer. There is no information available to assess if retailing of vine or loose tomatoes are of different risk for contamination by either *Salmonella* or Norovirus. Tomatoes may also be subject to further types of minimal processing (e.g. selection, washing, cleaning, stem removal, cutting, packaging and storage) and are also used for production of unpasteurised juices and 'smoothies' (sometimes mixed with other fruits or vegetables) usually for immediate consumption or with very short shelf lives.

At catering and in domestic environments, tomatoes are served fresh, often mixed with other vegetables or salad products as well as being added to complex foods such as sandwiches. Washing of

the product may take place in a similar manner to that outlined in primary processing, but is more likely to be in sinks with running potable water used for general food handling.

Tomatoes are also used with minimal processing such as in the cold soup gazpacho usually made with tomatoes, cucumbers, peppers, onions, garlic, olive oil and vinegar. The pH of the gazpacho is relatively low, (pH $\leq$ 4.5) although it will depend on the recipe. In the food industry, where it is generally used a standard ratio of ingredients, the composition is commonly 86 % tomato, 9.4 % olive oil, 2.2 % vinegar, 1.6 % salt and 0.8 % garlic. Similarly, other minimally processed tomato containing dished foods such as salsa can be prepared containing a mixture of foods of non-animal origin. Contaminated salsa was associated with a salmonellosis outbreak in the USA (Campbell et al., 2001).

7. Risk factors for microbiological contamination during distribution, retail and catering including domestic and commercial environments

Risk factors during distribution, retail and catering for tomatoes are likely to be the same or similar to those for leafy greens (EFSA BIOHAZ Panel, 2014a), although they are not generally as supported by published studies. The primary risk factors are contamination from the environment (e.g. hygiene of premises and storage rooms), cross-contamination through direct or indirect contact with contaminated water or equipment or handling by infected persons.

7.1. Water sources (washing)

As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a), water that has been contaminated with bacteria and viruses, and is then used in food preparation, can cause contamination of tomatoes. This represents a similar contamination or cross-contamination risk to that which can occur during processing (see Section 5.2). It has been shown that viruses (including Norovirus) can be transferred from contaminated liquid to the surfaces of other foods (Rodriguez-Lazaro et al., 2012). There is no direct experimental evidence for transfer of bacterial foodborne pathogens to tomatoes by this route, although it has the potential to occur.

7.2. Equipment

There is the possibility for Norovirus contamination from various food products to spread via cross-contamination through contact with food processing or preparation surfaces as previously discussed (EFSA BIOHAZ Panel, 2014a). For example, this could occur through cutting of a contaminated item followed by using the same utensil to cut uncontaminated items without adequate cleaning between each steps (Wang et al., 2013; Shieh et al., 2014).

Due to the wide diversity of foodstuffs potentially prepared and handled in catering establishments, cross-contamination of tomatoes from foodstuffs more frequently contaminated with *Salmonella* or other foodborne pathogens is a risk factor. The same risk for cross-contamination may exist at retail for tomatoes, although this has not been documented, probably because there is generally adequate segregation between tomatoes and other types of foods.

7.3. Worker health and hygiene, worker training

Contamination of leafy greens with both *Salmonella* and Norovirus through contact with the hands of infected persons during preparation was previously discussed (EFSA BIOHAZ Panel, 2014a), and similar risks occur with respect to the contamination of tomatoes. Poor hand hygiene (e.g. not washing thoroughly) following use of toilet facilities prior to handling of foodstuffs is an important and universal risk factor for contamination of food. Risk factors for tomato in a restaurant will include the potential for cross-contamination between products and utensils as well as from poor food handler and consumer hygiene. Although less documented than for Norovirus, contamination of tomatoes with *Salmonella* by food handlers is a potential risk. A Norovirus outbreak in Sweden among over 400 office workers who lunched in the companies' canteen was probably caused by an infected food handler who prepared the tomatoes for the salad buffet before vomiting at the workplace (Zomer et al.,

2010). This outbreak highlights the general nature of Norovirus transmission which might have incriminated other foods had the food handler been preparing other components of the meal.

There is also the possibility of malicious contamination which has the potential to cause large outbreaks (Torok et al., 1997).

7.4. Storage temperature.

Norovirus does not multiply in foods. Storage temperature influences the risk only to the extent of its persistence on the surface of contaminated tomatoes. However since it is not possible to perform infectivity assays, there is no information on the relative persistence of Norovirus on tomatoes at different storage temperatures. For *Salmonella*, although there is limited information, Zhuang et al. (1995) showed that *Salmonella* Montevideo which had gained access to the internal tissues of mature green tomatoes increased more than 10 fold when the fruits were stored at 20 °C for 18 days but exhibited no increase or declined when held at 10 °C.

As previously outlined in Section 5, *Salmonella* will grow on sliced, diced and cut tomatoes provided these are stored at temperatures allowing growth. There is also evidence for the survival of *Salmonella* Enteritidis in tomato juice (Mosqueda-Melgar et al., 2008), as well as growth at 12 and 21 °C over 200 hrs in minimally processed salsa, although this was dependent on the ingredients, particularly on the absence of lime juice and garlic (Ma et al., 2010). Salsa was associated with an outbreak of *Salmonella* Thompson, and there was evidence for a more than 3 log increase in this product after one day at 24 °C (Campbell et al., 2001).

7.5. Conclusion

At distribution, retail, catering and in domestic and commercial environments, cross-contamination of items, in particular via direct or indirect contact between raw contaminated food and tomatoes are the main risk factors for *Salmonella.* These cross-contamination risks include the environments of salad bars.

At distribution, retail, catering and in domestic or commercial environments, the Norovirus-infected food handler is the main risk factor. This can be direct or indirect via poor hand hygiene or food contact surfaces that have been subjected to cross-contamination. These contamination and cross-contamination risks include the environments of salad bars.

The use of contaminated water for washing of tomatoes or utensils, slicing equipment or working benches are other risk factors for both *Salmonella* and Norovirus. For *Salmonella* growth of the pathogen can occur when not stored at chilled temperature for prolonged periods.

Salmonella will grow on sliced, diced and cut tomatoes and some tomato products provided these are stored at temperatures which will allow growth. There is also evidence for the survival of *Salmonella* in tomato juice.

It is likely that Norovirus would be able to persist on fresh tomatoes during distribution, retail, catering, domestic or commercial environments through to consumption, although no direct information is available.

8. Analytical methods for the detection and enumeration of *Salmonella* in tomatoes

As previously outlined (EFSA BIOHAZ Panel, 2014a), methods for detection of *Salmonella* spp. in FoNAO are well developed and analytical reference methods standardised and widely adopted across laboratories testing food, including that for Official Control: EN/ISO standard method 6579[12] is

[12] EN/ISO 6579:2002. Microbiology of food and animal feeding stuffs - Horizontal method for the detection of *Salmonella* spp. International Organization for Standardization, Geneva, Switzerland.

prescribed in Regulation (EC) No 2073/2005[13] when analysing pre-cut ready-to-eat fruit and vegetables in the scope of the verification of compliance with the currently established food safety microbiological criterion for *Salmonella* spp. Alternative methods based on modifications of the ISO method using alternative enrichment media or isolation media (chromogenic media) or using immunoassays and real time PCR are also available for rapid detection of *Salmonella,* and many of these methods have been validated according to ISO 16140 showing performance characteristics equivalent to the EN/ISO standard method 6579 (EFSA BIOHAZ Panel, 2014a). ISO/CEN EN ISO 6887-4[14] is available and provides recommendations on (sub) sampling for microbiological testing.

9. Data on occurrence and levels of *Salmonella* in tomatoes

There is no routine or regular monitoring of tomatoes for the presence of *Salmonella* in EU Member States and there is very limited data on the occurrence of *Salmonella* in/on tomatoes although there are some studies available in the peer-reviewed world literature (Table 1). Contamination with *Salmonella* is more likely to occur on the surface of the tomatoes, thus some of the studies mentioned in Table 1 used a surface wash of the tomatoes, whereas others mentioned taking a standard 25 g (or other 10 to 600 g weight) representative sample. There is limited data available from studies on the occurrence of *Salmonella* on tomatoes, some of these studies are small (e.g. comprising < 20 samples) and provide limited data on the occurrence of this bacterium, some were done after the occurrence of specific risk factors (floods, ingress of animals in green houses), and there is no data on field grown tomatoes despite the outbreaks that have occurred in the US. Furthermore, there is limited data on the occurrence of *Salmonella* in samples collected in the EU: only two studies were located in the EU (Sagoo et al., 2001; Badosa et al., 2009). It is not possible to include data on contamination of tomatoes by *Salmonella* within Zoonoses monitoring data (according to the Directive 2003/99/EC[15]) since these data are aggregated into broad food categories, e.g. the single category of vegetables and fruits. Finally there is a variety of methods and sample sizes used making meaningful comparisons between individual studies difficult. Consequently, there are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of *Salmonella* contamination.

[13] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p. 1-26.

[14] ISO 6887-4:2003. Microbiology of food and animal feeding stuffs — Preparation of test samples, initial suspension and decimal dilutions for microbiological examination — Part 4: Specific rules for the preparation of products other than milk and milk products, meat and meat products, and fish and fishery products. International Organization for Standardization, Geneva, Switzerland.

[15] Directive 2003/99/EC of the European Parliament and of the Council of 17 November 2003 on the monitoring of zoonoses and zoonotic agents, amending Council Decision 90/424/EEC and repealing Council Directive 92/117/EEC. OJ L 325, 12.12.2003, p. 31-40.

Table 1: Studies on the occurrence of *Salmonella* in tomatoes

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI [(a)]	Sample size	Reference
Farms	Tomatoes (Roma, cherry and beefsteak)	USA	USDA BAM	238	0	0	[0,1]	25 g	(Mukherjee et al., 2006)
On farm production in hydroponic greenhouses	Fresh tomatoes	Mexico	Enrichment in Tetrathionate, Rappaport-Vassilidis and selenite cystine broths with subculture to XLD, bismuth sulfite and Salmonella-Shigella Agar	681	19	2.8	[1.7,4.2]	Surface wash of 6 fruits	(Orozco et al., 2008a)
On farm production in hydroponic greenhouses	Fresh tomatoes	Mexico	Compendium of Methods for Microbiological Examination of Foods American Public Health Association 2001	906	63	7.0	[5.4,8.7]	Surface wash of 6 fruits	(Orozco et al., 2008b)[(b)]
Domestic	Tomatoes	USA	NS	198	0	0	[0,1.3]	16 oz	(US-FDA, 2003)
Import	Tomatoes	USA from various countries[(c)]	NS	20	0	0	[0,11.7]	16 oz	(US-FDA, 2001)
Retail	Fresh organic tomatoes	UK	PHLS F21 (ISO 6579)	428	0	0	[0,0.6]	25 g	(Sagoo et al., 2001)
Retail	Fresh tomatoes	Spain	ISO 6579 (Plus real-time PCR)	5	0	0	[0,37.9]	25 g	(Badosa et al., 2009)
Retail (market and supermarket)	Fresh bola and saladette (Roma)tomatoes	Mexico	Mexican Official protocol (NOM SSA1 1994)	40	1	2.5	[0.3,11.1]	25 g	(Cárdenas et al., 2013)
Wholesale and distribution centers (domestic and imported)	Tomatoes	USA	ELISA	2706	0	0	[0,0.1]	NS	(USDA, 2002)
Retail (distribution centres and markets)	Fresh market tomatoes	Canada	Health Canada Compendium of Analytical Methods MFHPB-20	141	1	0.7	[0.1,3.3]	25 g	(Arthur et al., 2007)
Retail farmer's markets	Fresh tomatoes	Canada	Health Canada MFLP-29	120	0	0	[0,2.1]	25 g	(Bohaychuk et al., 2009)
Retail	Tomatoes	Japan	Enrichment in Rappaport-Vassilidis and Tetrathionate, subculture to XLD, DHL and MLCB	1140	1	0.1	[0,0.4]	25 g	(Hara-Kudo et al., 2013)
Retail markets and street vendors	Fresh tomatoes	Saudi Arabia	Rappaport-Vassilidis enrichment screened by PCR	4	0	0	[0,44.5]	25 g	(Hassan et al., 2011)

(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).
(b): During the course of this study, two independent natural events affected the farm, namely water runoff entered some of the greenhouses and wild animals (opossums, mice and sparrows) gained entry into several of the greenhouses.
(c): Belgium, Mexico, the Netherlands

10. Analytical methods for the detection and enumeration of Norovirus in tomatoes

Information on the standardisation of methods for detection of Norovirus in foods can be found in Sections 4.3.2 of the Scientific Opinion of the EFSA BIOHAZ (EFSA Panel on Biological Hazards (BIOHAZ), 2011a).

There are two ISO/CEN methods[16] which are currently available for Norovirus detection and quantification respectively in food. These methods have now the status of a Technical Specification (TS), and, based upon validation data, will need to be to reviewed three years after initial publication before becoming a full International Standard[17]. The methods are technically complex, and performance strictly according to the technical specifications can only be carried out in specialised and well-resourced laboratories with skilled personnel. In particular, the production of the nucleic acid controls is challenging, and the availability of reliable quality control materials and External Quality Assurance (EQA) schemes will be necessary before there can be complete confidence in the concordance of results between laboratories. These ISO/CEN methods are currently technical specifications and have the opportunity to be further refined with regard to sampling, sample preparation, limit of detection and interpretation of results. To date, there are few reports of analytical methods for Norovirus detection on tomatoes. ISO/TS 15216-1 and ISO/TS 15216-2 refer to detection of Norovirus on leafy green vegetables and berry fruit. However, it should be possible to apply them to the detection of Norovirus on tomatoes. The firm surface of this fruit allows virus to be washed off during the sample processing steps, although the efficiency for this has not been fully determined.

11. Data on occurrence of Norovirus in tomatoes

There is no routine or regular monitoring of tomatoes for the presence of Norovirus in EU Member States and there are very limited data on occurrence of Norovirus in/on tomatoes in the peer-reviewed world literature (Table 2). It is not possible to include data on the occurrence of Norovirus in tomatoes within Zoonoses monitoring data (according to the Directive 2003/99/EC) since these data are aggregated into broad food categories, e.g. the single category of vegetables and fruits. Some limited data are available on contamination (see following text); however, there are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of Norovirus contamination.

[16] ISO/TS 15216-1: Microbiology of food and animal feed - Horizontal method for determination of hepatitis A virus and norovirus in food using real-time RT-PCR - Part 1: Method for quantification. International Organization for Standardization, Geneva, Switzerland.
ISO/TS 15216-2: Microbiology of food and animal feed - Horizontal method for determination of hepatitis A virus and norovirus in food using real-time RT-PCR - Part 2: Method for qualitative detection. International Organization for Standardization, Geneva, Switzerland.

[17] International Organization for Standardization. ISO deliverables. ISO/TS technical specification. Available online: http://www.iso.org/iso/home/standards_development/deliverables-all.htm?type=ts

Table 2: Studies on the occurrence of Norovirus on tomatoes

Sampling place	Commodity	Sampling country	Number of samples analysed	Number of samples where Norovirus detected	% of positive samples	95 % CI[(a)]	Reference
Trading company	Cherry tomatoes	Belgium	30 (10 samples each of 3 batches)	7	23.3	[11.1,40.4]	(Stals et al., 2011b)[(b)]
Catering	Tomatoes	Turkey	95	1	1.1	[0.1,4.8]	(Yilmaz et al., 2011)[(c)]

(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).
(b): Size of tomato samples was 20 g.
(c): Size of tomato samples was 25 g.

These samples were analysed in the course of two research surveys, of which only one occurred in the EU and were not known to be linked to any outbreaks. The analyses used methods similar to the standardised methods described in ISO/TS 15216-1 and ISO/TS 15216-2, in general or specific aspects.

Stals et al. (2011a) detected Norovirus in 7 out of 30 samples of cherry tomatoes whereas in two samples of cherry tomatoes both Norovirus genogroups I and genogroup II signals were present. It should be noted that usually one and maximally two out of four replicate RT-qPCRs per sample gave a positive signal in samples where NoV genomic presence was detected, which can be explained by the fact that most detected NoV signals were close to the presumed detection limit of the NoV RT-qPCR methodology (also noticeable from associated Ct values of the positive samples ranging between 37 and 42). Analysing tomatoes from salad bars and restaurants in Istanbul Yilmaz et al. (2011) found 1 sample contaminated with Norovirus GII out of the 95 tested. Serracca et al. (2012) tested dried tomatoes purchased at an open-air market in Italy for Norovirus. They found 6/13 samples from national Italian production and 6/12 samples imported from Turkey to be Norovirus-positive, while 3/5 samples of semi-dried tomatoes in oil (tomatoes from Turkey) were NoV-positive.

12. Mitigation options to reduce the risk for humans posed by *Salmonella* or Norovirus in tomatoes

12.1. Introduction

Many of the mitigation options previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a) are generic and equally applicable to other foods of non-animal origin, including tomatoes, however there are differences which are inherent to this fruit. Tomatoes are a substantially different commodity when compared to leafy greens with respect to the production system, their intrinsic characteristics and epidemiological evidence associating their consumption with food-borne outbreaks. Tomatoes are pulpy fruit with a high moisture content and a relatively soft skin, which makes them susceptible to physical damage, pest infestation and microbial spoilage. Enteric bacteria may occur on the surface of tomatoes under certain circumstances particularly if there has been recent direct or indirect exposure to animal or human faecal contamination. Tomatoes for fresh market are primarily produced in greenhouses, although differences in the type of production can be observed within the EU. They are usually grown high above the ground, which reduced the risk of splashing from the soil. Following processing, *Salmonella* is able to grow in cut product and Norovirus is likely to persist on tomatoes throughout the food-chain.

12.2. General mitigation options

Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing tomatoes. These food safety management systems should be implemented along the farm to fork continuum and will be applicable to the control of a range of

microbiological hazards. Although some intervention strategies or control measures can be defined to prevent, limit the spread or sometimes reduce the level of contamination in tomatoes, the main focus for food safety management should be on preventive measures, as it is difficult or not possible to define critical control points (CCPs) that either eliminate the microbial hazard or substantially reduce it. Codes of practice and guidelines should encourage the use of appropriate good agricultural and hygiene practices at farm level. Food safety management based on GMP and HACCP principles should be the objective of processors, distributors, retailers and caterers involved in production of ready-to-eat tomatoes. Outside EU there are commodity specific food safety guidelines for the fresh tomato supply chain which provide recommended food safety practices that are intended to minimize the microbiological hazards associated with fresh and fresh-cut tomato products (Suslow, 2004; North American Tomato Trade Work Group and United Fresh Produce Association, 2008; US-FDA, 2009a).

In addition, the responsibilities of food business operators producing or harvesting plant products require them to take adequate control measures as outlined in Regulation (EC) No. 852/2004[18] and these are identical to those outlined previously for leafy greens eaten raw as salads (EFSA BIOHAZ Panel, 2014a). Where practicable, a comprehensive food safety control plan should be developed. This should include a written description for each hazards identified when assessing environmental hygiene at primary production and the steps that will be implemented to address them (EFSA BIOHAZ Panel, 2014a).

Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. Each farm environment (including open field or greenhouse production) should be evaluated independently as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of foodborne pathogens in or near tomato growing areas. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, intervention strategies should be applied to restrict growers from using this land for primary production until the hazards have been addressed, or the products should be sent for processing which, for example, may include a heating step which is likely to eliminate microbiological hazards.

There should be complete traceability through primary production, processing, distribution, retail, and catering to consumption of all tomatoes or tomato products.

12.2.1. Environment

As outlined for leafy greens (EFSA BIOHAZ Panel, 2014a), primary production should not be carried out in areas where the known or suspected presence of foodborne pathogens that could potentially be transferred to horticultural crops intended for human consumption without a validated process kill step (CAC, 1969, 2003). Preventive measures are not always easy to implement as farmers may not control adjacent land activities or the land history does not include knowledge of the extent or level of foodborne pathogens in the soil or the time necessary to reduce these to acceptable levels (Suslow et al., 2003; James, 2006; Gil et al., 2013).

Some tomatoes frequently come into contact directly with soil during growth and/or harvesting. Bird droppings and airborne contaminants (birds nesting around the packing area, nearby livestock, poultry areas or manure storage or treatment facilities, etc.) may also pose a risk of contaminating tomatoes. Growers should use production practices (e.g. site selection, wind breaks) to minimize exposure of tomatoes to airborne contaminants and limit contact of tomatoes with the soil, animal droppings, soil amendments (including natural fertilizers) or direct contact with irrigation water. Where materials are used under growing tomatoes plants to minimize contact with the soil (e.g. mulch or biodegradable materials (e.g. straw)) or during harvest (e.g. plastic or biodegradable materials (e.g. leaves or papers as liners of biodegradable baskets)) to collect harvested fruits, it is recommended that during growing, plastic surfaces which can come into contact with tomatoes should be clean and sanitary. If

[18] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p.1-54.

biodegradable materials and/or mulch are used, they should be applied only once and not reused in order to prevent cross-contamination.

Growers should implement safe handling, transport and storage practices. Cold storage and immediate cooling of tomatoes after harvesting will prevent multiplication of *Salmonella* in case it has been internalized inside the fruit or in case of tomatoes kept under high humidity (packaged tomatoes). When precooling is required growers should use potable quality water for ice and hydro-coolers. Tomatoes that have undergone cleaning and/or chemical treatment should be separated, either physically or by time, from raw material and environmental contaminants. Whenever tomatoes need to be washed, cross-contamination should be prevented between raw and washed tomatoes, from sources such as wash water, rinse water, equipment, utensils and vehicles. Since tomatoes are intended to be consumed raw, sorting and selection should be implemented to avoid using fruits that have visible signs of decay or damage due to the increased risk of microbial contamination.

Premises and rooms should be designed to separate areas for incoming tomatoes from the field (areas for incoming soiled tomatoes) from those used for subsequent handling. This can be accomplished in a number of ways, including linear product flows. Where feasible, raw material handling areas should be separated from processing/packing areas. Within each of these areas, cleaning operations should be conducted separately to avoid cross-contamination between equipment and utensils used in each operation. For products that are not immediately wrapped or packed (i.e. the tomatoes might be exposed to contaminants from the environment), the rooms where final products are packaged and stored should be designed and maintained to be as dry as possible. The use of water or having a wet environment enhances the growth and spread of foodborne pathogens and spoilage organisms.

Because tomatoes are very susceptible to mechanical damage they are usually manually harvested, which enhance the hand-manipulation by agricultural workers. Tomatoes are susceptible to damage during harvest and post-harvest handling operations. The following should be considered:

- avoid setting tomatoes directly on soil after removal from the plant and before loading into transport vehicle to avoid contaminating the tomatoes with contaminants in the soil;
- minimize mechanical damage as wounds may provide entry points for foodborne pathogens and sites for microbial survival and multiplication;
- train agricultural workers to recognize and discard or segregate damaged tomatoes.

12.2.2. Manure and sewage sludge

As for leafy greens, appropriate production, storage, management and use of manure and sewage sludge are important for tomato production to reduce residual foodborne pathogen populations (EFSA BIOHAZ Panel, 2014a). Treatment procedures to reduce or eliminate foodborne pathogens from contaminated manure are, as with any ready-to-eat food, equally applicable. The key considerations regarding the use of sewage sludge in tomato production are the same as those previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a).

12.2.3. Water

12.2.3.1. Water in primary production

Selection of appropriate irrigation sources is important for tomato production and avoiding, if possible, uncontrolled water sources such as rivers and lakes was previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a). Other possible corrective actions may include fencing to prevent large animal contact to water sources, proper maintenance of wells, filtering water, not disturbing the sediment when drawing water, building settling or holding ponds, and water treatment. Among the potential interventions, both efficient drainage systems that take up excess overflows and water treatment (at primary production and processing) are needed to prevent the additional dissemination of

contaminated water. Since *E. coli* is an indicator micro-organism for faecal contamination in irrigation and process water, growers should arrange for periodic testing to be carried out to inform preventive measures. Most tomatoes are intended for direct consumption; however, for tomatoes that are washed, it is recommended to monitor and control the quality of the water used, i.e. tests for indicator organisms and/or foodborne pathogens, to avoid contamination.

12.2.3.2. Process wash water

In Europe, all tomatoes for minimal processing are washed in a dump tank (Appendix A, Freshfel information). Thus, special attention should be paid to maintain the quality of the process wash water. Mitigation strategies aiming to reduce risks of microbial contamination for all water used during processing was previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014a). As an example, chlorine at 40-60 mg free chlorine per litre may be used when washing tanks or fluming are used. However, there are many disinfectant agents commercially available that can be used to maintain the quality of the water such as chlorine dioxide, peracetic acid and hydrogen peroxide among others. Most of the GAP guidelines recommend the use of potable quality water during processing and this should include wash-water where used, as well as that used for refreshing, refrigeration, cooling, ice or other uses. If water is used for cooling and is recirculated, it should be evaluated and monitored to ensure that water management is documented and part of the HACCP plan.

12.2.4. Equipment

The importance of clean equipment as a preventive measure to avoid contamination of equipment associated with growing and harvesting was previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a) and the same considerations should be applied for tomato production and processing. Priority attention should be given to hygiene of containers used for field packing of tomatoes which will not be washed by the harvester or processor prior to their sale to the consumer. This will help minimize the possibility of microbial contamination through additional handling steps. Growers should ensure that clean pallets and containers (disinfected where necessary if not single use) are used and that the containers do not come into contact with soil and manure during field packing operations.

12.2.5. Workers

The importance of standard enforceable policies and provision of training in sanitation for all employees working in primary production, processing, retail and catering was emphasised for leafy greens (EFSA BIOHAZ Panel, 2014a). Compliance with hygiene requirements, in particular hand hygiene, is an absolute necessity for food handlers at all stages of the tomato production and supply chain to reduce the risks of both *Salmonella* and Norovirus contamination. Only workers who have been trained in hygienic handling should be assigned to pick, pack or process tomatoes. It is important to minimize post-harvest handling of tomatoes to maximise product shelf life and avoid the introduction of foodborne pathogens or other contaminants. It is also important to recognize and document field contamination indicators (e.g. broken fences, animal droppings, high incidence of insects) and take appropriate actions to mitigate associated risks. In addition, the importance of correct tomato handling techniques should be emphasised to minimize or prevent damage to the fruit and associated microbial contamination. All persons involved in the handling of tomatoes should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

12.2.6. Final product

Consumers should be advised to avoid the purchase of trays or cases with damaged or rotten tomatoes. Since transporting tomatoes to home can raise the product temperature, particularly in the summer months, storing tomatoes in a cool environment, refrigeration as soon as possible and once removed from the refrigerator, consuming tomatoes as soon as possible would prevent multiplication of *Salmonella* if it contaminates the inside tissues of the fruit or if the fruit is maintained under high humidity (i.e. packaged tomatoes).

Consumers should be advised on how to handle, prepare, and store tomatoes safely to avoid cross-contamination with foodborne pathogens from various sources (e.g. hands, sinks, cutting boards, utensils, raw meats). They should also be given guidance on correct hand washing methods, and the need to wash tomatoes with potable water before consumption.

It is recommended that pre-cut tomatoes should be wrapped/packaged and refrigerated as soon as possible and distributed under refrigeration temperatures (i.e. 4 °C or less).

It is important to provide consumers with adequate information on handling tomatoes, recommending to:

- keep the time in transit for pre-cut tomatoes between retail/market and the home as short as possible, as increase in product temperature during transportation can be considerable;
- all pre-packaged and pre-cut tomatoes (as well as tomatoes pre-cut at home) should be refrigerated as soon as possible;
- consume pre-cut tomatoes as soon as possible, once removed from the refrigerator;
- for whole, unpackaged tomatoes, cold storage would prevent multiplication of *Salmonella* if it contaminates the inside tissues of the fruit.

12.2.7. Conclusions

Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing tomatoes. These food safety management systems should be implemented along the farm to fork continuum and will be applicable to the control of a range of microbiological hazards.

Attention should be paid to the selection of the water source for irrigation, agricultural chemical application (e.g. pesticides and fungicides) and in particular, avoiding the use or the ingress of sewage contaminated water.

The existing requirements in CODEX documents or EU Hygiene Regulation for growers and producers producing or harvesting tomatoes are very general in nature and leave room for interpretation e.g. use potable quality water, or clean water, whenever necessary to ensure that foodstuffs are not contaminated.

Apart from avoiding the use of sewage-contaminated water at all stages of the supply chain, the main mitigation options for reducing the risk of Norovirus contamination on tomatoes are adherence to hand hygiene by food handlers at all stages of the supply chain (see Section 12).

In primary production compliance with existing prerequisite programmes such as Good Agricultural Practices (GAP) and with recommended Codes of Practices and guidance such as the relevant Codex guidelines, will assist *Salmonella* and Norovirus risk mitigation strategies. During processing Good Manufacturing Practices (GMP) and food safety management systems (including HACCP) will also assist *Salmonella* and Norovirus risk mitigation strategies.

Food safety management based on GMP and HACCP principles should be the objective of processors, distributors, retailers and caterers involved in production of tomatoes.

The evaluation of water quality, water treatment technologies or other risk mitigation options (e.g. selection of appropriate agents for cleaning and disinfection) for Norovirus is limited by the current lack of suitable methods for *in vitro* determination of Norovirus infectivity, and current NoV

RT-qPCR-based detection and monitoring methods are unable to discriminate between infectious and non-infectious virus particles.

Clear information (including labelling) should be provided to consumers on appropriate handling of tomatoes which includes specific directions for product storage, preparation, intended use, and shelf life indicators.

12.3. Specific mitigation options to reduce the risk of *Salmonella* contamination

As *Salmonella* has reservoirs in domestic as well as in wild animals, birds and humans, the main mitigation options for reducing the risk of contamination of tomatoes are to prevent direct contact with faeces as well as indirect contact through slurries, organic amendments and contaminated soil, water, equipment or food contact surfaces.

Most tomatoes are not treated or only minimally treated. Temperature remains one of the most important intervention measures to reduce *Salmonella* growth in tomatoes. Zhuang et al. (1995) reported that the population of *S.* Montevideo in whole inoculated tomatoes stored at 10 °C did not change significantly throughout an 18-day storage period, while 3 log cfu/g increases in population both occurred within 7 days and within 1 day when tomatoes were stored packaged in plastic bags at 20 and 30 °C, respectively.

In some instances, tomatoes are subjected to post-harvest treatment (e.g. controlled or modified atmosphere packaging, gaseous ozone, 1-Methylcyclopropene (1-MCP)) particularly for the prevention of fungal spoilage and extension of the shelf-life (Freshfel information, Appendix A). Controlled and modified atmospheres did not significantly affect the decline rate of *S.* Enteritidis on tomatoes with initial population of 7.0 $\log_{10}$ cfu/tomato when stored at 7 °C (Daş et al., 2006). However, in the case of initial population of 3.0 $\log_{10}$ cfu/tomato, the log reduction of *S.* Enteritidis on the surfaces of tomatoes that were stored in modified atmosphere packaging (MAP) (6 % O_2 and 4 % CO_2) was faster than that of stored in air and in controlled atmospheres (15-17 O_2 and 5 % CO_2) (Daş et al., 2006). The application of gaseous ozone treatments was shown to have a bactericidal effect on *S.* Enteritidis, inoculated on the surface of the tomatoes and could be used for surface sanitation of *S.* Enteritidis on tomatoes before storage at different conditions. Ten mg/l ozone gas treatment with different time intervals of 5 and 15 min was found to be effective respectively on low and high dose inoculum levels of *S.* Enteritidis attached for 1 h (Daş et al., 2006). Other gaseous treatments have been also applied. Obaidat and Frank (2009) reported that allyl isothiocyanate equivalent to 83.3 µl/litre of air inactivated *Salmonella* on whole tomatoes to the detection limit of < 2 log CFU/tomato at 4 and 10 °C in 10 d and by 1.3 log cfu/tomato at 25 °C in 10 h. Overall, greater inactivation occurred at 10 than at 4 °C and on the tomato surface than between tomato slice study. As far as we know, the impact of 1- methylcyclopropene on the survival or growth of foodborne pathogenic micro-organisms such as *Salmonella* spp. has not been determined.

Tomatoes intended for fresh market or minimal processing can be washed in water or chlorinated water, although other sanitizing treatments can be also used (Freshfel information, Appendix A). As stated previously for leafy greens (EFSA BIOHAZ Panel, 2014a) washing alone will have some effect in reducing the microbiological (including foodborne pathogens) biota whilst also creating the potential opportunities for cross-contamination to occur, and this is equally applicable to tomatoes. Therefore, the microbial quality of the process water should be maintained using a disinfection treatment, to avoid cross-contamination.

The efficacy levels of different physical and chemical washing treatments in the reduction of *Salmonella* spp. in tomatoes have been reported. However, this information is often derived from experimental studies with low strength of evidence, which have been carried out under artificial conditions which cannot be extrapolated to the processing line (e.g. high doses, extended contact times, and use of potable quality water with minimal organic matter). The different experimental set up of these studies also makes difficult the comparison between different studies.

Valadez et al. (2012) have published a comprehensive review on the inactivation efficacy of different sanitizing treatments. The results included in this review indicated that immersion of surface inoculated tomatoes in water for 1 min alone reduced *S. enterica* by ~ 1.2 log CFU/cm^2 (Pao et al., 2007). When chlorine was used, populations of *S.* Montevideo were significantly reduced by dipping for 2 min in a solution containing 60 or 110 ppm free chlorine, but further increases in chlorine concentration did not result in complete inactivation (Zhuang et al., 1995). Similar results were reported by other authors who found *Salmonella* spp. reductions of about 1-2 log cfu/g after washing tomatoes in chlorinated water containing between 100-200 ppm free chlorine (Bari et al., 2002; Lu and Wu, 2010; Mattson et al., 2011). Several studies have shown that efficacy of aqueous chlorine solutions against populations of *Salmonella* spp. varied depending on the location of the bacteria with significant differences between the surface, wounded areas, or stem scars of tomatoes (Wei et al., 1995; Yuk et al., 2005; Felkey et al., 2006). Effectiveness of 1200 ppm acidified sodium chlorite wash and 87 ppm peroxyacetic acid on smooth surface, stem scar tissue, and puncture wound of tomatoes up to 4 log cfu/g has been reported (Yuk et al., 2005). Chlorine gas (200 ppm free chlorine) and hydrogen peroxide (5 %) have been also tested showing *Salmonella* reductions of 1.34 log CFU/g (Cl_2) and 1.45 log CFU/g (H_2O_2) after 2 min at 60 °C in whole tomatoes (Sapers and Jones, 2006).

Pao et al. (2007) studied the efficacy of chlorine dioxide (ClO_2) on *S. enterica* inoculated on tomatoes and a disinfection agent to avoid cross-contamination between different batches. Treatments of 20 ppm of ClO_2 for 1 min were needed to achieve a 5-log reduction of *S. enterica* on freshly spot-inoculated tomatoes while *Salmonella* air–dried onto the surface of tomatoes at 24 °C for 24 h were not significantly reduced after 20 ppm of ClO_2 treatment for 1 min when compared to untreated control (Pao et al., 2007). However, ClO_2 was able to prevent cross-contamination at an immersion concentration of 5 ppm for effectively inactivate *Salmonella* in process water (Pao et al., 2007). The efficacy of high-concentration-short-time ClO_2 gas treatments reducing *Salmonella enterica* on Roma tomatoes was evaluated by Trinetta et al. (2010). *Salmonella* reductions of up to 5 log cfu/cm^2 were obtained treating tomatoes with 10 mg/l for 180 s. Other authors have reported the efficacy of ClO_2 gas treatments on whole tomatoes at lower concentrations 0.1- 4 mg/l showing *Salmonella* reductions between 1 and 5 log cfu/g (Sy et al., 2005; Bhagat et al., 2010).

Raiden et al. (2003) evaluated the efficacies of 0.1 % sodium lauryl sulfate and 0.1 % Tween 80 (polysorbate 80) in removing *Salmonella* from the surfaces of vine tomatoes at different treatment temperatures. Starting with an inoculum size of 6 log cfu/g, levels of between 1.5 to 4 cfu/g were removed as determined by the analysis of the rinsing solutions.

The efficacy of plant-derived biomolecules such as carvacrol, trans-cinnamaldehyde, eugenol and β-resorcylic acid as a wash treatment for reducing *Salmonella* spp. on tomatoes was also investigated. Mattson et al. (2011) demonstrated that if the plant molecules were used in the washing water they were more effective in reducing *Salmonella* on tomatoes compared to washing in water and chlorinated water at 200 ppm. Carvacrol, trans-cinnamaldehyde and eugenol decreased *Salmonella* counts on Plum tomatoes by ~ 6.0 log CFU/ml. Lu and Wu (2010) also evaluated the antibacterial activities of thymol (0.2 or 0.4 mg/ml), carvacrol (0.2 or 0.4 mg/ml), and thyme oil (1 or 2 mg/ml) against *Salmonella* spp. on grape tomatoes during the washing procedure. Thymol was the most effective among the three natural antimicrobial agents, which achieved > 4.1 log reductions of *S. enterica* serovars Typhimurium, Kentucky, Senftenberg, and Enteritidis on grape tomatoes after a 5-min washing and >4.3 log CFU/ml reductions after a 10-min washing.

Irradiation of tomatoes was shown to be an efficient treatment to reduce *Salmonella* populations on artificially inoculated tomatoes. Irradiation doses of 1.9 to 2.4 kGy obtained a 5 log reduction of *Salmonella* from sliced Roma tomatoes (Niemira, 2011). Mahmoud (2010) also showed that lower irradiation doses of 0.75 kGy X-ray were also effective reducing 3.7 log CFU/tomato of *S. enterica* on whole Roma tomatoes, while 5 log CFU/tomato reduction was achieved at 1.0 or 1.5 kGy X-ray. The differences observed between these two research studies could be related to the type of tissue treated, cut surfaces vs whole tomato surface. High pressure processing at 350, 450, 550 (MPa) applied to

whole tomatoes inoculated with 6.33 log CFU/g managed a 4.15 log CFU/g reduction after 2 min at 20 °C (Maitland et al., 2011).

Tomatoes inoculated with about 10^7 cfu/g on the suface and treated with acidified electrolized water significantly reduced the inoculum concentrations by more than 5 logs when compared to the untreated control when potable water was used (Park et al., 2009). However, when the organic matter of the process water is increased and the free chlorine available is reduced due to the reaction with the organic matter, the *S.* Typhimurium loads were not statistically reduced after treatment compared to the water control (Park et al., 2009). Ozonated water for washing has been also tested to reduce *Salmonella enterica* Typhimurium loads on tomato fruits. Inoculated grape tomatoes with about 10^5 log cfu/g of *S.* Typhimurium were treated with ozonated water for 1, 5 and 10 min at room temperature, mild heated (50 °C) and refrigerated (4 °C) at pH 5.6 and 2.6 (Xu and Wu, 2014). Results demonstrated that *Salmonella* inactivation by ozonated water was time-dependent and mild heat and pH 2.6 seemed to improve efficacy of ozonated water against *S.* Typhimurium on tomatoes reducing by 2 to 3 log cfu units when compared to unwashed tomatoes (Xu and Wu, 2014).

Combined treatments such as the use of chlorine dioxide plus UV-C irradiation have also been tested and shown to be very active at reducing up to 6 log cfu/g of inoculated *Salmonella* spp. (Song et al., 2011).

The temperature differential between tomato and process water also seems to be a factor affecting *Salmonella* spp. internalization. Zhuang et al. (1995) reported that a significantly higher number of cells was taken up by the core tissue of tomatoes tempered at 25 °C when the tomatoes were dipped in a suspension at 10 °C compared with the number taken up when the tomatoes were dipped in cell suspensions tempered at 25 or 37 °C. However this finding was challenged by other results (see Sections 3.3 and 3.1.1).

In conclusion for tomatoes, chemical sanitizers, applied either as a gas or as aqueous solutions, and physical treatments permit reduction in the surface contamination of *Salmonella*. However the extent of this reduction depends on the type of tomato, the site of contamination on the tomato, the treatment used and may be limited by the impact of the decontamination treatment on tomato quality, which has rarely been assessed during tomato shelf-life.

12.4. Specific mitigation options to reduce the risk of Norovirus contamination

Information on existing preventive measures for Norovirus contamination in place according to current EU legislation and control options for FoNAO can be found in Sections 6.2 of the Scientific Opinion of the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards (BIOHAZ), 2011a), in the Codex Guidelines on the application of general principles of food hygiene to the control of virus contamination of food (CAC, 2012), and in guidance sheets produced by the FP7 project "Integrated monitoring and control of foodborne viruses in European food supply chains" (available at http://www.eurovital.org/). Available guidance is general and does not refer specifically to individual food commodities such as tomatoes.

As human pathogenic Norovirus have their reservoir in humans (there is no proven zoonotic reservoir) the main sources within the environment from which contamination of food by Norovirus can arise include sewage-contaminated water and as a consequence sewage sludge. Norovirus can be found in high concentrations in raw sewage, and also in sewage sludge (Rao et al., 1986). The process of sewage treatment produces high volumes of sludge; the Urban Waste Water Treatment Directive 91/271/EEC[19] encourages the application of sewage on to agricultural land as fertiliser; however to reduce the likelihood of foodborne pathogen contamination of crops subsequently grown, the Directive forbids the application to soil on which vegetable crops are grown for less than 10 months prior to harvest. The reduction in infectivity of Norovirus in sewage-amended soil over this period is not known.

[19] Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment. OJ L 135, 30.05.1991, p. 40-52.

The Codex Guidelines on the application of general principles of food hygiene to the control of virus contamination of food (CAC, 2012) recommend that potential sources of viral contamination of the environment should be identified prior to production activities, and that primary food production should not be carried out in areas where the presence of viruses may lead to viral contamination of food, e.g. in close proximity to a sewage treatment plant where there might be discharges of sewage water in the surface water, as even sewage treated by modern systems such as filtration can contain high levels of Norovirus (Nenonen et al., 2008).

Norovirus may be found in waters that could act as sources of supply during primary production, e.g. ground water (Cheong et al., 2009; Borchardt et al., 2012) and river water (Wyn-Jones et al., 2011; Maunula et al., 2012) which they can contaminate via the ingress of sewage, e.g. through outflow from a sewage treatment plant, or failure of a sewerage system. Fresh waters in the environment offer excellent conditions for the survival of enteric viruses (Rzeżutka and Cook, 2004), and it is highly likely that Norovirus will be able to survive in an infectious state in river and groundwater after introduction via a sewage pollution event, during irrigation or washing or pesticide application (Verhaelen et al., 2013). Untreated water used in primary production and/or processing is therefore a major vehicle for virus contamination of tomatoes, and thus a key control point. The Codex guidelines for control of virus contamination of food (CAC, 2012) recommend that efforts should be made to use only clean water during production and processing, and that corrective actions should be taken if sources of contamination are identified. Possible corrective actions include disinfection e.g. by chlorine. The effectiveness of chlorine against Norovirus activity is not fully defined due to the lack of an infectivity assay, although studies observing the effect of chlorination on detectable viral RNA (Shin and Sobsey, 2008) indicate that chlorine concentrations used to treat drinking water would be effective in reducing/eliminating Norovirus.

Regulation (EC) No 852/2004 requires that equipment which comes in contact with food should be effectively cleaned and where necessary, disinfected. The efficacy of currently available surface disinfection treatments against Norovirus is not fully certain, and EFSA has recommended (EFSA Panel on Biological Hazards (BIOHAZ), 2011a) that effort should be focussed on avoiding viral contamination rather than trying to remove/inactivate viruses in food.

Infected persons handling food during harvesting, processing and catering are major sources for Norovirus contamination of foods. Viruses can be transferred from the hands or fingertips onto food items or food preparation surfaces, particularly under moist conditions (Bidawid et al., 2000). Persons with symptoms of gastroenteritis, including vomiting, should be excluded from working in food production (i.e. including harvesting and processing) until their symptoms have subsided, e.g. for 48 hours (EFSA Panel on Biological Hazards (BIOHAZ), 2011a). However, as pre- and post-symptomatic shedding can occur (Atmar et al., 2008) this exclusion may not be entirely sufficient to prevent the possibility of food contamination from occurring, and returning employees should pay special attention to hand hygiene. Scrupulous compliance with hand hygiene practices such as effective washing is an absolute necessity for all food supply chain employees, and should be emphasised in local codes of practice and training manuals.

Information on effects of treatments used in food processing on noroviruses can be found in Sections 4.2 and 4.2.1 of the Scientific Opinion of the EFSA BIOHAZ Panel (EFSA Panel on Biological Hazards (BIOHAZ), 2011a).

In conclusion, the main mitigation options for reducing the risk of Norovirus contamination on tomatoes are scrupulous adherence to hand hygiene for food handlers, and avoiding the use of sewage-contaminated water at all stages of the supply chain. Compliance with existing prerequisite programmes such as GAP and GMP, and with recommended general guidance such as the relevant Codex guidelines, will assist mitigation strategies.

The evaluation of water quality, water treatment technologies or other risk mitigation options (e.g. selection of appropriate agents for cleaning and disinfection) for Norovirus are hampered by the

current lack of suitable methods for *in vitro* determination of Norovirus infectivity (Richards, 2012) and current NoV RT-qPCR detection and monitoring methods are unable to discriminate between infectious and non-infectious virus particles (Knight et al., 2013) (see Section 12.1).

13. *E. coli* as a microbiological indicator in tomatoes

Monitoring of indicator organisms is routinely used by the industry, environmental agencies and public health organizations to verify effective implementation of Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP) for a wide range of foods and food manufacturing processes (Efstratiou et al., 2009; Wilkes et al., 2009; Ferguson et al., 2012). However it should be emphasised that testing should never be relied upon as a food safety management strategy, but rather should verify the effectiveness of existing risk management strategies (Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), Good Manufacturing Practices (GMP) and HACCP). As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a), when testing pre-cut ready-to-eat fruit and vegetables in the scope of the verification of compliance with the currently established Process Hygiene Criterion for *E. coli*, EN/ISO standard methods 16649-1[20] or 16649-2[21] are generally available and are prescribed in Regulation (EC) 2073/2005.

14. Data on occurrence of *E. coli* in tomatoes

There are limited studies which have enumerated *E. coli* in/on tomatoes and these relate to fresh tomatoes produced outside the EU (Table 3). It is of note that there is no data on field grown tomatoes or from samples taken from supermarkets. Some of the studies have taken relatively few samples (e.g. comprising < 20 samples) and a variety of methods and sample sizes used in all the studies summarised in Table 3. Consequently there are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination.

Since there is a lack of data on the occurrence and levels of *E. coli* in tomatoes, it is not currently possible to establish relationships between production and processing practices and numbers of *E. coli.* However, as previously discussed for leafy greens (EFSA BIOHAZ Panel, 2014a), *E. coli* is commonly present in faecal material and has general use as a hygiene indicator. Consequently, because *E. coli* is present in high numbers in faecal material (e.g. fresh manure) and likely to decline in the soil and on the surfaces of tomatoes during primary production, it can be considered as an indicator of a recent exposure to risk factors for *Salmonella*. However, there is currently insufficient available data to assess the effectiveness of *E. coli* to verify compliance to Good Agricultural Practices (GAP), Good Hygiene Practices (GHP), Good Manufacturing Practices (GMP) and food safety managements systems (including HACCP) in the production of tomatoes.

E. coli is not suitable as an indicator for Norovirus contamination in shellfish (Lees, 2000): however there is insufficient information to establish if this is also true in other food types including tomatoes.

[20] EN/ISO 16649-1:2001. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of betaglucuronidase-positive *Escherichia coli* - Part 1: Colony-count technique at 44 degrees C using membranes and 5-bromo-4-chloro-3-indolyl beta-D-glucuronide. International Organization for Standardization, Geneva, Switzerland.

[21] EN/ISO 16649-2:2001. Microbiology of food and animal feeding stuffs - Horizontal method for the enumeration of betaglucuronidase-positive *Escherichia coli* - Part 2: Colony-count technique at 44 degrees C using 5-bromo-4-chloro-3-indolyl beta-D-glucuronide. International Organization for Standardization, Geneva, Switzerland.

Table 3: Studies on the occurrence of *E. coli* in tomatoes

Sampling place	Commodity	Sampling country	Detection method	Number of samples analysed	Number of positive samples	% of positive samples	95 % CI[(a)]	Detection limit	*E. coli* levels	Reference
On farm production in hydroponic greenhouses	Fresh tomatoes	Mexico	Compendium of Methods for Microbiological Examination of Foods American Public Health Association 2001 (MPN)	681	5	0.7	[0.3,1.6]	0.5 MPN per fruit	Median range < 0.5-30 MPN/tomato	(Orozco et al., 2008a)
On farm production in hydroponic greenhouses	Fresh tomatoes (before flood)	Mexico	Compendium of Methods for Microbiological Examination of Foods American Public Health Association 2001 (MPN)	110	3	2.7	[0.8,7.1]	<5 cfu/g	NS	(Orozco et al., 2008b)
	Fresh tomatoes (during flood)			4	2	50.0	[12.3,87.7]	< 5 cfu/g	NS	
	Fresh tomatoes (after flood)			32	6	18.8	[8.2,34.6]	< 5 cfu/g	NS	
	Fresh tomatoes (before entry wild animals)			30	2	6.7	[1.4,19.7]	< 5 cfu/g	NS	
	Fresh tomatoes (during entry wild animals)			242	135	55.8	[49.5,61.9]	< 5 cfu/g	NS	
	Fresh tomatoes (after entry wild animals)			66	18	27.3	[17.7,38.8]	< 5 cfu/g	NS	
Retail (distribution centres and markets)	Fresh market tomatoes	Canada	Petrifilm	141	ND	0	[0,1.8]	< 5 cfu/g	<5 cfu/g	(Arthur et al., 2007)
Retail farmer's markets	Fresh tomatoes	Canada	Health Canada MFHPB-19 MPN	120	0	0	[0,2.1]	MPN	NS	(Bohaychuk et al., 2009)
Retail markets and street vendors	Fresh tomatoes	Saudi Arabia	Eosin methylene blue agar (AOAC Compendium of Methods for Microbiological examination of Foods 2001)	4	ND	0	[0,44.5]	NS	ND	(Hassan et al., 2011)

NS = not stated
NA = not applicable
ND = not detected
(a): The credible interval was calculated using a Bayesian approach and taking as prior beta (1/2,1/2) (Miconnet et al., 2005).

15. Microbiological criteria for tomatoes

EU Food hygiene legislation (Regulation (EC) No 852/2004) lays down minimum hygiene requirements; official controls are in place to check food business operators' compliance and food business operators should establish and operate food safety programmes and procedures based on HACCP principles. Regulation (EC) No 2073/2005 on microbiological criteria (MC) for foodstuffs is an implementing measure of the food hygiene legislation applicable since January 2006. It is important to emphasize that the safety of food is predominantly ensured by a preventive approach, such as implementation of GAP, GMP, GHP and application of procedures based on HACCP principles while microbiological criteria can be used for validation and verification of these procedures. This is also the main principle in the legislation. In the European Union legislation, in relation to tomatoes, microbiological criteria have been established for *Listeria monocytogenes* in all ready- to-eat foods, for generic *E. coli* and *Salmonella* in ready-to-eat pre-cut fruit and vegetables, and for unpasteurised fruit and vegetable juices (see Sections 15.2.1 and 15.2.2). There are no microbiological criteria for fresh tomatoes. There is no official Food Safety Criterion for Norovirus in tomatoes.

Considerations on the establishment of Microbiological Criteria should be made on the basis of public health goals which are intended to inspire actions to improve the future public health status and reduce the disease burden (EFSA, 2007). Tomatoes have been implicated in one outbreak of salmonellosis and one of Norovirus infection in Europe between 2007 and 2011 (EFSA Panel on Biological Hazards (BIOHAZ), 2013). In 2011, there was a *Salmonella* Strathcona outbreak associated with tomatoes in the EU. The outbreak included a total of 43 culture confirmed human cases. The overall conclusion of the investigations was that the tomatoes were the source of the outbreak in Denmark with a high probability. In Denmark the tomatoes in question had been sold during September and the first part of October 2011. Since no stock was left it was not possible to perform microbiological analyses on the tomatoes. There had been also 14 *Salmonella* Strathcona cases in Germany and 1 in Austria. A total of 13 salmonellosis outbreaks associated with tomato consumption have been reported in the USA and Canada (CDC, 2007; Hanning et al., 2009; Barton Behravesh et al., 2011; Behravesh et al., 2012) with more than 3900 cases. In the majority of the outbreaks, contamination occurred at production or during minimal processing.

In the EU there was a single Norovirus outbreak reported in 2007 associated with tomatoes with over 400 cases amongst Swedish office workers from the same unit of a manufacturing company in Stockholm. Tomatoes from the salad buffet in the canteen were among the most likely vehicles of infection. Norovirus GI.3 was identified in stool samples from three office workers and from a food handler who prepared the tomatoes for the salad buffet before vomiting at the workplace (Zomer et al., 2010). In summary, epidemiological data from the EU has only identified one salmonellosis outbreak and one Norovirus outbreak associated with tomato consumption between 2007 and 2012.

There are limited studies on the occurrence of *Salmonella* or Norovirus on tomatoes, of which only a few reported results from surveys executed in EU Member States (Tables 1 and 2): it is not possible to assess the representativeness of these occurrence data and there is no information on the adequacy of the implementation of GAP and/or other food safety systems (including HACCP) associated with the presence of these pathogens.

15.1. Hygiene Criteria for tomatoes at primary production

The current legal framework does not include microbiological criteria applicable at the primary production stage. It is part of the growers' responsibility to validate and verify Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP) for tomato production. For this purpose criteria, designated as Hygiene Criteria could be used. For example *E. coli* was identified as suitable for a Hygiene Criterion at primary production of leafy greens indicating the acceptable functioning at pre-harvest, harvest and on farm post-harvest production prior to processing (EFSA BIOHAZ Panel, 2014a).

Common production practices for tomatoes differ from those of leafy greens and reduce the likelihood of contamination by enteric pathogens. For instance, protected and soilless culture, which represents a large part of tomatoes production units in some EU areas together with greater use of drip irrigation offers less opportunities for faecal contamination of the tomatoes than, for example, open field production of leafy greens with overhead irrigation using contaminated surface water. In addition, there is a lack of data from Europe on the presence and levels of enteric bacteria such as *Salmonella* and generic *E. coli* on tomatoes. The current lack of data does not allow the proposal of a Hygiene Criterion for *E. coli* at primary production of tomatoes. However, using *E. coli* as an indicator of recent human or animal faecal contamination is likely to be useful for verification of GAP and GHP at individual production sites (e.g. to assess clean water used for irrigation and other water uses such as for the application of pesticides and fertilizers, and food handlers' hands), for example during prerequisite compliance audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator. Consequently if water is contaminated with *E. coli* there is a higher risk for the occurrence of Norovirus and *Salmonella* in the water and, hence, tomatoes will also have a higher risk of contamination by Norovirus and *Salmonella*.

Even if there is currently insufficient evidence to warrant the establishment of an *E. coli* Hygiene Criterion for tomatoes, growers should focus on the appropriate implementation of Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP) with special attention to 1) appropriate management of manure which might include aerobic composting, anaerobic digestion, aeration of sludge, and stabilization; 2) maintenance of the microbial quality of irrigation water and the water used for pesticides application, for which a water treatment might be necessary, 3) cleaning and disinfection of contaminated equipment, and 4) strict control of the worker hygiene. In addition, growers should provide information to the manager of the subsequent step in the food chain.

15.2. Process Hygiene Criteria for tomatoes

As defined in the legislation, a Process Hygiene Criterion is a criterion indicating the acceptable functioning of a production process. In Regulation (EC) No 852/2004) processing is defined as any actions that substantially alter the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes. In the scope of this Opinion, only minimally processed tomatoes are considered, i.e. those where any action is only applied to the initial product (e.g. cleaning, chopping, slicing or dicing and washing) and which is not included above in the definition of processing. Process Hygiene Criteria are only applicable to food business operators and not to primary producers.

There are currently Process Hygiene Criteria for *E. coli* in samples collected during the manufacturing process (n = 5; c = 2; m = 100 cfu/g and M = 1,000 cfu/g) for ready-to-eat pre-cut fruit and vegetables as well as unpasteurised fruit and vegetable juices (Regulation (EC) No 2073/2005). In the scope of this Opinion this microbiological criterion only applies to ready-to-eat pre-cut tomatoes and unpasteurised tomato juices. However, there is insufficient information available on the occurrence and levels of *E. coli* in pre-cut, mashed and other minimally processed tomatoes and therefore the suitability of this criterion cannot be assessed. For this reason it is therefore not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion for these products. However, using *E. coli* as an indicator for verification of GMP and food safety management systems (including HACCP) might be useful for tomatoes in individual processing premises e.g. during food safety management audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

15.3. Food Safety Criteria for tomatoes

As previously outlined for leafy greens (EFSA BIOHAZ Panel, 2014a), the EU Food Safety Criteria defined in EU legislation are for the microbiological acceptability of food products. These criteria apply to products at the end of production or placed on the market. If the criteria are not met the product/batch is expected to be withdrawn from the market. The following conclusions concerning Food Safety Criteria were previously stated (EFSA, 2007):

(a) An advantage of establishing Food Safety Criteria for pathogenic micro-organisms is that harmonised standards on the acceptability of food are provided for both authorities and industry within the EU and for products imported from third countries.

(b) Food Safety Criteria will impact the entire food chain, as they are set for products placed on the market. Risk of recalls and the economic loss as well as loss of consumer confidence will be a strong motivation to meet the criteria. Therefore Food Safety Criteria are assumed to have an effect on food safety and public health where there is an actual or perceived risk. However, it is not possible to evaluate the extent of public health protection provided by a specific Food Safety Criterion.

(c) Microbiological testing alone may convey a false sense of security due to the statistical limitation of sampling plans, particularly in the cases where the hazard presents an unacceptable risk at low concentrations and/or low and variable prevalence.

(d) Food safety is a result of several factors. Microbiological criteria should not be considered without other aspects of EU Food legislation, in particular HACCP principles and official controls to audit food business operators' compliance.

In order to establish Food Safety Criteria, it is a prerequisite that methods to properly detect the hazard are available. The sensitivity and specificity of the detection method should always be taken into account. Regulation (EC) No 2073/2005 on microbiological criteria does not prescribe any sampling/testing frequencies except for minced meat, mechanically separated meat and meat preparations. While this leaves flexibility to tailor the intensity of testing according to the risk, it also leaves the possibility of inconsistency in testing and control (EFSA, 2007).

Epidemiological data have identified salmonellosis outbreaks associated with tomato consumption. There are Food Safety Criteria for the absence of *Salmonella* in 25g samples (n = 5; c = 0) of ready-to-eat pre-cut fruit and vegetables as well as unpasteurised fruit and vegetable juices for products placed on the market during their shelf life (Regulation (EC) No 2073/2005). Consequently the Food Safety Criterion in Regulation (EC) No 2073/2005 requires an absence of *Salmonella* in 25 g samples (n = 5; c = 0) of ready-to-eat pre-cut tomatoes as well as in unpasteurised tomato juice placed on the market during their shelf life. Although there are only few data for *Salmonella* on tomatoes in the EU (i.e. 0 out 428 in fresh organic tomatoes in UK), from the reported studies in North America (Table 1), the occurrence of *Salmonella* on whole tomatoes is variable. Based on outbreak data from the EU and USA/Canada, a Food Safety Criterion for *Salmonella* in whole tomatoes could be considered as a tool to communicate to producers and processors that *Salmonella* should not be present in the product. Since the occurrence of *Salmonella* is likely to be low, testing of whole tomatoes for this bacterium could be limited to instances where other factors indicate breaches in GAP, GHP, GMP or HACCP programmes.

For Norovirus, there is very limited occurrence data in the world wide literature and only one outbreak was reported in the EU between 2007 and 2012, due to a (vomiting) food handler during buffet preparation in catering, thus it is currently not possible to provide a risk base for establishing a Food Safety Criterion for these foods. Furthermore, the methodology used for detection and quantification of Norovirus in tomatoes requires improvement regarding the sampling, sample preparation, limit of detection and quantitative accuracy. Also real time RT-PCR does not discriminate between infectious and non-infectious Norovirus (Knight et al., 2013) and therefore presents a greater level of uncertainty than that for most bacteria since it may overestimate or underestimate the risk.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- Tomatoes, for the scope of this Opinion, are defined according to commercial production and consumption as the fruit from a small herbaceous plant, *Lycopersicum esculentum* Miller, which belongs to the *Solanaceae* family and grows under warm conditions.
- Tomatoes may be minimally processed to obtain ready-to-eat products, and these steps include selection, washing, cleaning, stem removal, cutting, packaging and storage. Other types of processing (e.g. freezing, mashing and juicing without pasteurisation etc) rarely occur outside retail and catering and are not further considered in this Opinion. Tomatoes may be also subject to cooking, drying, bottling, canning and other processes, but these are outside the scope of this Opinion.
- Tomatoes for fresh market are primarily produced in greenhouses, although differences in the type of production can be observed within the EU and small-scale growers still use open field-cultivation in some countries if climatic conditions allow.
- Tomato production in greenhouses can be carried out using soil or soil-less systems. Soil-cultivated tomatoes in greenhouses use similar techniques to those used for open field cultivation. Soil-less systems include a great diversity of processes, from the purely hydroponic, to those based on artificial mixes that contain various proportions of different substrates.
- Open-field tomatoes are usually cultivated using plastic mulch on raised beds. In open field production, plastic mulch can be also used to promote early fruiting, reduce competition from weeds, and to conserve moisture and fertilizer. Drip irrigation is used most frequently in conjunction with plastic mulch.
- Tomatoes are usually harvested by hand into picking buckets or boxes. The picking buckets or boxes are then transported to a centralized packinghouse where the fruit is further processed.
- Optimal storage temperatures range between 10 and 13 °C. The recommended storage temperature of tomatoes differs with the cultivar and the maturity of the fruit. Usually tomatoes are sensitive to chilling at temperatures below 10 °C if held for longer than 2 weeks below 10 °C if held for longer than 2 weeks or at 5 °C for longer than 6-8 days.
- Whole tomatoes are generally not waxed or washed before packaging. Production from soil-based systems may however be washed to remove dust, surface dried, sized and packed. In the case of products destined for the fresh-cut market, the products are washed prior to cutting.
- Fresh and minimally processed tomatoes are normally not subjected to physical interventions that will eliminate the occurrence of *Salmonella* and Norovirus.

Answers to the Terms of Reference

TOR 3. To identify the main risk factors for the specific food/pathogen combinations identified under ToR 2, including agricultural production systems, origin and further processing.

- The risk factors for the contamination of tomatoes with *Salmonella* are poorly documented in the EU with limited available data in the literature but are likely to include the following, based on what is known for other pathogenic bacteria or other types of fresh produce:
    - environmental factors, in particular proximity to animal rearing operations and climatic conditions that increase the transfer of pathogens from animal reservoirs to the tomato plants;

  - contact with animal reservoirs (domestic or wild life) gaining access to tomato growing areas;
  - use of untreated or insufficiently treated organic amendments;
  - use of contaminated water either for irrigation or for application of agricultural chemicals such as pesticides and
  - contamination or cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

- The risk factors for the contamination of tomatoes with Norovirus in the EU are also poorly documented in the literature with limited available data but are likely to include the following, based on what is known for other pathogens or other fresh produce:
  - environmental factors, in particular climatic conditions (e.g. heavy rainfall) that increase the transfer of Norovirus from sewage or sewage effluents to irrigation water sources or to tomato growing areas;
  - use of sewage contaminated water either for irrigation or for application of agricultural chemicals such as pesticides and
  - contamination and cross-contamination by harvesters, food handlers and equipment at harvest or post-harvest.

- The ability of *Salmonella* to survive on or in tomatoes is cultivar dependent and the growth stage of the plant also represents an important factor for internalization of *Salmonella* through the root system, suggesting that plants are more susceptible to internalization immediately after transplantation.

- Several studies reported that *Salmonella* internalization can occur through the porous tissues of the stem scar and this internalization usually occurs within the core tissue segments immediately underneath the stem scars.

- Even if *Salmonella* is located on the tomato surface, it can be transferred to the flesh during further handling or cutting and can survive or even grow, as some *Salmonella* serovars have demonstrated the ability to survive on different parts of the tomato plant.

- No information is available on the potential for Norovirus to internalise within or survive on tomatoes.

- For both *Salmonella* and Norovirus, processes at primary production which wet tomatoes represent the highest risk of contamination with both pathogens, and these include spray application of agricultural chemicals such as fungicides and, if applied, the use of overhead irrigation.

- During minimal processing, contamination or cross-contamination via equipment, water and via food handlers are the main risk factors for fresh or cut tomatoes for *Salmonella*.

- For *Salmonella*, the risk of cross-contamination during washing (whenever applied), is reduced if disinfectants are properly used within the washing tank. The effectiveness of disinfectants against Norovirus is not fully defined due to the lack of an infectivity assay.

- *Salmonella* has been shown to persist on the surface of intact tomatoes.

- It is likely that Norovirus would be able to persist through the procedures involved in minimal processing of fresh tomatoes, although no direct information is available.

- At distribution, retail, catering and in domestic and commercial environments, cross-contamination of items, in particular via direct or indirect contact between raw contaminated food and tomatoes are the main risk factors for *Salmonella.* These cross-contamination risks include the environments of salad bars.

- At distribution, retail, catering and in domestic or commercial environments, the Norovirus-infected food handler is the main risk factor. This can be direct or indirect via poor hand hygiene or food contact surfaces that have been subjected to cross-contamination. These contamination and cross-contamination risks include the environments of salad bars.

- *Salmonella* will grow on sliced, diced, cut tomatoes and some tomato products provided these are stored at temperatures which will allow growth. There is also evidence for the survival of *Salmonella* in tomato juice.

TOR 4. To recommend possible specific mitigation options and to assess their effectiveness and efficiency to reduce the risk for humans posed by food/pathogen combinations identified under ToR 2.

- Appropriate implementation of food safety management systems including Good Agricultural Practices (GAP), Good Hygiene Practices (GHP) and Good Manufacturing Practices (GMP) should be the primary objective of operators producing tomatoes. These food safety management systems should be implemented along the farm to fork continuum and will be applicable to the control of a range of microbiological hazards.

- As *Salmonella* has reservoirs in domestic as well as in wild animals, birds and humans, the main mitigation options for reducing the risk of contamination of tomatoes are to prevent direct contact with faeces as well as indirect contact through slurries, organic amendments and contaminated soil, water, equipment or food contact surfaces.

- Apart from avoiding the use of sewage-contaminated water at all stages of the supply chain, the main mitigation options for reducing the risk of Norovirus contamination on tomatoes are scrupulous adherence to hand hygiene by food handlers at all stages of the supply chain. Persons with symptoms of gastroenteritis, including vomiting, should be excluded from working in food production until their symptoms have subsided.

- Attention should be paid to the selection of the water source for irrigation, agricultural chemical application (e.g. pesticides and fungicides) and in particular avoiding the use or the ingress of sewage contaminated water.

- Compliance with existing prerequisite programs such as Good Agricultural Practices (GAP) and Good Manufacturing Practices (GMP), and with recommended Codes of Practices and guidance such as the relevant Codex guidelines, will assist *Salmonella* and Norovirus risk mitigation strategies.

- Production areas should be evaluated for hazards that may compromise hygiene and food safety, particularly to identify potential sources of faecal contamination. If the evaluation concludes that contamination in a specific area is at levels that may compromise the safety of crops, intervention strategies should be applied to restrict growers from using this land for primary production until the hazards have been addressed.

- Each farm environment (including open field or greenhouse production) should be evaluated independently as it represents a unique combination of numerous characteristics that can influence occurrence and persistence of foodborne pathogens in or near tomato growing areas.

- Among the potential interventions, both efficient drainage systems that take up excess overflows and water treatment (at primary production and processing) are needed to prevent the additional dissemination of contaminated water. Since *E. coli* is an indicator micro-organism for faecal contamination in irrigation and process water, growers should arrange for periodic testing to be carried out to inform preventive measures.

- All persons involved in the handling of tomatoes should receive hygiene training appropriate to their tasks and receive periodic assessment while performing their duties to ensure tasks are being completed with due regard to good hygiene and hygienic practices.

- Consumers should be advised on how to handle, prepare, and store tomatoes safely to avoid cross-contamination with foodborne pathogens from various sources (e.g. hands, sinks, cutting boards, utensils, raw meats).

TOR 5. To recommend, if considered relevant, microbiological criteria for the identified specific food/pathogen combinations throughout the production chain.

- Epidemiological data from the EU have identified one salmonellosis outbreak and one Norovirus outbreak associated with tomato consumption between 2007 and 2012.

- There is no routine or regular monitoring of tomatoes for the presence of *Salmonella* in EU Member States and there is very limited data on the occurrence of *Salmonella* in/on tomatoes in Europe although there are some studies available in the peer-reviewed world literature. There are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of *Salmonella* contamination.

- There is no routine or regular monitoring of tomatoes for the presence of Norovirus in EU Member States and there are very limited data on the occurrence of Norovirus in/on tomatoes in the peer-reviewed world literature. There are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of Norovirus contamination.

- There are limited studies which have enumerated *E. coli* in/on tomatoes and these relate to fresh tomatoes produced outside the EU. There are difficulties in both making meaningful comparisons between individual studies as well as assessing the representativeness of these data to estimate the overall levels of contamination.

- The current legal framework does not include microbiological criteria applicable at the primary production stage. The current lack of data does not allow the proposal of a Hygiene Criterion for *E. coli* at primary production of tomatoes.

- There is insufficient information available on the occurrence and levels of *E. coli* in pre-cut, mashed and other minimally processed tomatoes and therefore the suitability of this criterion cannot be assessed. For this reason it is therefore not possible to assess the suitability of an EU-wide *E. coli* Process Hygiene Criterion for these products. Using *E. coli* as an indicator for verification of GMP and food safety management systems (including HACCP) might be useful for tomatoes in individual processing premises e.g. during food safety management audits, where epidemiological studies indicated a higher risk of infection or at the discretion of the food business operator.

- The Food Safety Criterion in Regulation (EC) No 2073/2005 requires an absence of *Salmonella* in 25 g samples (n = 5; c = 0) of ready-to-eat pre-cut tomatoes as well as in unpasteurised tomato juice placed on the market during their shelf life.

- A Food Safety Criterion for *Salmonella* in whole tomatoes could be considered as a tool to communicate to producers and processors that *Salmonella* should not be present in the product. Testing of whole tomatoes for *Salmonella* could be limited to instances where other factors indicate breaches in GAP, GHP, GMP or HACCP programs.

- Although Noroviruses have been detected in tomatoes, occurrence studies are limited, and quantitative data on viral load are scarce. For Norovirus, there is very limited occurrence data in the world wide literature and only one outbreak was reported in the EU between 2007 and 2012, due to a (vomiting) food handler during buffet preparation in catering, thus it is currently not possible to provide a risk base for establishing a Food Safety Criterion for these foods.

- The methodology used for detection and quantification of Norovirus in tomatoes does not discriminate between infectious and non-infectious Norovirus and therefore presents a greater level of uncertainty than that for most bacteria since it may overestimate or underestimate the risk.

RECOMMENDATIONS

- More detailed categorization of food of non-animal origin should be introduced to allow disaggregation of the currently reported data collected via EFSA's zoonoses database on occurrence and enumeration of foodborne pathogens.

- ISO technical specifications for Norovirus detection and quantification on tomatoes should be further refined with regard to sampling, sample preparation, limit of detection, quantitative accuracy and interpretation of results.

- There should be implementation and evaluation of procedures such as sanitary surveys, training, observational audits and other methods to verify agricultural and hygiene practices for tomatoes.

- Further data should be collected to evaluate the suitability of *E. coli* criteria at both primary production and during minimal processing of tomatoes.

- Risk assessment studies are needed to inform the level of hazard control that should be achieved at different stages of tomato production and minimal processing. Such studies should be supported by targeted surveys on the occurrence of *Salmonella* and Norovirus in tomatoes at specific steps in the food chain to identify the level of hazard control and efficacy of application of food safety management systems, including GAP, GHP, GMP and HACCP, that has been achieved at different stages of production systems.

- Research should be undertaken with the aim of: a) developing infectivity assays for Norovirus and b) investigating survival of foodborne pathogens including internalisation in tomatoes during crop production at natural exposure levels.

- Further data should be collected to evaluate the suitability of bacterial or viral indicators for monitoring Norovirus and other relevant microbiological hazards in tomatoes and in tomato production and processing environments. Monitoring for suitable indicators could include water used in primary production, and also applied to food handlers' hands, and could be performed during audit to verify compliance with good practice.

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APPENDICES

Appendix A. List of questions to be addressed by the European Fresh Produce Association (Freshfel) and information received from Freshfel on 22 July and 24 November 2013

1. How do you categorise tomatoes according to different:
   - production systems,
   - processing (excluding thermal treatment or any equivalent (e.g. blanching as well as shelf stable juices) and
   - presentation at retail?

   All questions below aim at characterizing the tomatoes sector in the EU.

PRODUCTION SECTOR

2. Provide an overview of this sector listing the most commonly produced botanical varieties of tomatoes in the EU?
3. Which are the top 10 types of tomatoes produced in EU?
4. Which are the top 10 types of tomatoes sold in EU?
5. Which countries are the major producers in the EU?
6. Which are the main third countries providing the EU with tomatoes?
7. Which is the share of the market covered by imported production versus intra-EU production of tomatoes?
8. What is the share of producers of tomatoes which are not members of Freshfel in the EU?

   Which volume of production do these producers represent?
9. Are there any figures in the EU to characterize the proportion of the production of tomatoes from "home/small scale" producers when compared to "large-scale" production?
10. Provide available figures on (i) production, (ii) producers, (iii) trade, (iv) certification and (v) distribution (type of outlets) of the tomatoes.

AGRICULTURAL PRODUCTION SYSTEMS

11. Are there any producer's survey results which could help to describe how tomatoes are produced in the EU?
12. Characterise the profile of workers in the production of tomatoes (e.g. training, casual workers, foreign workers etc).
13. Please indicate percentages of production of tomatoes (i) in fields, (ii) in greenhouses, (iii) soilless (hydroponics) or (iv) in soil?
14. Are there any additional production systems in place in the EU (as well as for imported products)?
15. Which tomatoes can be produced as hydroponic crop?
16. Indicate the major irrigation systems and water sources in the agricultural production of tomatoes.

    Is the water quality controlled (microbiologically)? If so and if available, provide, data on microbiological quality of the water used in the agricultural production of tomatoes.

PROCESSING OF TOMATOES

17. Which are the most common processing practices for tomatoes in the EU?
18. Which agricultural practices and processing steps - can be executed (i) only manually, (ii) both manually or mechanically or (iii) preferentially mechanically?

    What are the percentages of manual versus mechanical practices?
19. Indicate the major water sources in the processing of tomatoes.

    Is the water quality controlled (microbiologically)? If so and if available, provide data on microbiological quality of the water used in the processing of tomatoes.
20. How important is the share of production in the EU for different tomatoes categories proposed in the scope of the answer to question 1?

    Which proportion of tomatoes are (i) sold directly (without further processing) or (ii) undergoing processing (peeling, pre-cutting, packaging and drying)?

DISTRIBUTION AND RETAIL

21. Which are the procedures and conditions for transport and distribution of tomatoes in the EU?

    Are there any specific cooling practices in place for tomatoes at harvest or post-harvest storage (or long distance transport)?
22. Are there any specific control measures in place in the EU to maintain the cold chain during storage and distribution of tomatoes?

    Are there any specific control measures in place to maintain long term storage?
23. Which proportion of tomatoes may be sold without temperature control during distribution in the EU?
24. Describe how traceability of tomatoes is addressed for the different agricultural production systems and processing options?

SYSTEMS IN PLACE TO ENSURE SAFETY OF PRODUCTS

25. Are there any European guidelines/codes available from Freshfel or other associations of producers on practices (including peeling, pre-cutting, packaging and drying) to ensure food safety in the production of tomatoes?
26. In your view, what are the strengths and weaknesses of the current GAPs, GMPs and standards to ensure microbiological quality of tomatoes?
27. In your view, which are the major weak points from the microbiological point of view in the agricultural production systems as well as in the processing of tomatoes?
28. Do the producers of peeled/pre-cut/pre-packaged/dry tomatoes in the EU need to be registered as food processing establishments?
29. What are the hygienic requisites that these processing establishments need to comply with?

    How is compliance with these hygienic requisites verified?
30. Are there any central repositories of data on non-compliance with the GAPs, GMPs, standards as well as on the analysis of these data?
31. Are there many companies producing tomatoes which are applying the “test to release” for microbiological parameters? If so, are companies using presence/absence tests? In case enumeration testing is used, which are the threshold levels (cfu/g) used for interpretation of the analysis results?

32. Are the producers, producer associations or any other stakeholders (e.g. retail) also doing regular testing/monitoring of tomatoes?
33. Which are the sampling plans used in the scope of this testing/monitoring of tomatoes?
34. Is there any additional testing/monitoring in place for imported tomatoes?
35. Does Freshfel have any available data in the EU on levels of detection and enumeration of *Salmonella* and Norovirus in tomatoes?
36. Which methods for detection and enumeration of *Salmonella* and Norovirus in tomatoes are being used in the food chain in the EU?
37. Which are the differences on the hygienic requisites for the production of organic tomatoes when compared to conventional production?

    How is compliance with these hygienic requisites verified?
38. What are the hygienic requisites in place for imported tomatoes?

    How is compliance with these hygienic requisites verified?
39. Which chemical and/or physical decontamination methods are being used in the EU for the treatment of soil, substrates, manure or compost?
40. Which chemical and/or physical decontamination methods are being used in the EU for the treatment of water (reservoirs, irrigation systems, processing water)?
41. Describe the practices in use in the EU for chemical and/or physical decontamination of tomatoes? Which are the main methods in place in the EU?
42. Which chemical and/or physical decontamination methods are allowed in the EU among Member States?
43. Does Freshfel provide specific recommendations on methods used to reduce contamination of tomatoes by *Salmonella* and Norovirus?

Information received from the European Fresh Produce Association (Freshfel) on 22 July and 24 November 2013

freshfel
EUROPEAN FRESH PRODUCE ASSOCIATION

Enjoy Fresh
Fruits & Vegetables

24 November 2013

Background information tomato category

Opinion EFSA-Q-2012-00177

Definitions (questions 1-2)

(1)Categorisation

A. Production

- Substrate / soil
- Open air / protected (greenhouse, polytunnels, …)
- Heated / unheated
- Vine / not on the vine

B. Processing
C. Retail presentation

Fresh

- Loose in the shelf, either in wooden crates, plastic crates or cardboard
- Flow-packed plastic or cardboard trays/punnets
- Closed plastic punnets (heat sealed or clip-lids)

Processed

- Prepared salads

(2) Varieties

The following commercial types are commonly produced (see also UN-ECE standard FFV-36 concerning the marketing and commercial quality control of tomatoes, 2012):

- Round
- Ribbed
- Oblong (aka prune tomatoes)
- "cherry" tomatoes (including "cocktail" tomatoes)

These commercial types are presented on the vine or loose. In addition there are specialties featuring tomatoes with a special colour or unusual shape (e.g. Kumato, Coeur de Boeuf).

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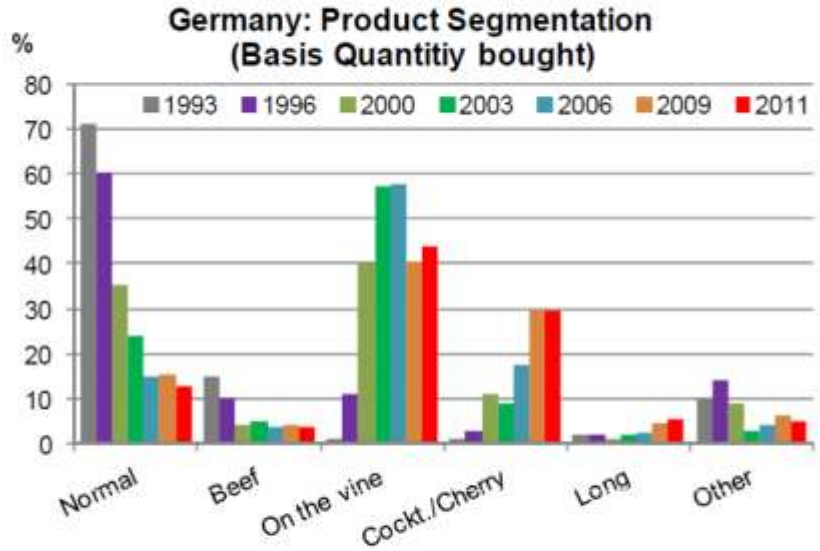
EU market (questions 3-10, 20)

(10) Detailed statistics are available in a yearly updated EU Commission working document prepared for the Forecast Working Group on Tomatoes. The data provided relate to the production in the EU, imports from 3rd countries and intra-EU import flows for each product. All data have been obtained from EUROSTAT.

(5-7) Tomatoes on the EU market are pre-dominantly produced in Southern Europe (Spain, Italy, Greece), with a significant volume also being produced in glasshouses in Northern European Countries (Netherlands, France, Belgium, ...). The share of imports from 3rd countries amounts to 7% corresponding to counter-seasonal supplies originating mainly from Morocco, Turkey and Israel.

(3-4) The most important commercial types are round tomatoes on the vine, cherry tomatoes, loose round tomatoes, beef tomatoes and plum tomatoes. There are no EU-wide statistics on the segmentation, but German GfK consumer panel data suggest the following sales shares: round tomatoes on the vine (44%), cherry tomatoes (30%), loose round tomatoes (13%), beef tomatoes (4%), plum tomatoes (5%); the remainder consisting of specialties.



Source: AMI-Analysis on Basis of GfK Panel

(20) Close to 7 million MT tomatoes are grown for the fresh market, compared to close to 9 million MT for the processing market (tomato concentrate/juice). The fresh-cut market segment is marginal and limited to those tomatoes used in prepared salads, although prepared salads generally tend to include cherry tomatoes to avoid processing tomatoes (short shelf-life).

(9) With regard to the differentiation between commercial production and home or small-scale production, there are no reliable figures available. Whereas home or small-scale production of tomatoes considered as marginal in Western Europe, it is more prevalent in certain Eastern European countries. The economic crisis and certain trends (local produce, authenticity) may however have contributed to an increased popularity of the segment.

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Agricultural production systems (questions 11-16)

(11) Tomatoes can be grown in several production systems ranging from open air to high-tech capital intensive glasshouses. All systems are continuously being optimised through research and innovation There are no survey results describing how tomatoes are produced in the EU.

(13-15) Tomatoes for the fresh market are mostly (90-95%) grown in greenhouses, the remainder being grown in open air in season. In Southern Europe tomatoes are mostly grown in low technology greenhouses from August until April (summer months mostly used to apply soil decontamination through solarisation), while In Northern Europe year-round production (January-December, 2-3 weeks for clearing the old crop and cleaning the premises) takes place in heated glasshouses. Similarly the majority of production will take place in soil in Southern Europe while substrate systems (rockwool, coco peat) are most common in Northern Europe.

Tomatoes are grown from tomato plants which are transplanted after an initial production phase of 6 weeks with the plant breeder.

(16) The major irrigation system used in tomato production is drip irrigation. The main water sources include surface waters (river, lake), reservoirs supplied by well water or rain water, and well water. In the case of products destined for the fresh market, the water quality is mostly controlled just once per year. In general E. Coli, Salmonella, Streptococcus faecalis, and total coliforms are the parameters being analysed.

(12) The field staff in the production of tomatoes mainly consists of seasonal workers from various countries depending on the production countries (e.g. North Africa in the case of Italy or Spain, Eastern Europeans in Northern European countries). In the packinghouse, there's a mix between national and foreign workers. The workers are trained with regard to the prevention of food safety incidents, which is generally a prerequisite.

Processing tomatoes (questions 17-19)

(17) The most common processing practices for the fresh-cut market include:

- Washing: all tomatoes for processing are washed in a dump tank
- Cutting: in parts, slices or pieces depending of the retail presentation
- Packing: in closed plastic salad bowls (heat sealed or clip-lids) under modified atmosphere.

(18) All agricultural (including harvest) practices are taking place manually; processing (i.e. cutting) mostly takes place mechanically. In many cases tomatoes are also manually cut in the final consumer outlet (restaurant, supermarket).

(19) The main water sources used in the processing practices are drinking water and potable well water. The water is tested according the applicable microbiological standards for potable water.

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Distribution & retail

(21) Tomatoes are generally cooled, the optimal temperature ranges from 8 to 15 °C. Transport from Southern Europe to the Northern European consumer markets on average take 1,5 days. Tomatoes can be stored for a maximum of 2-3 weeks, the use of ethylene inhibitors may however be used to prolong the shelf life even further.

Systems in place to ensure safety of products

(41) Tomatoes are generally not washed, production from soil-based systems may however be washed to remove dust. In the case of products destined for the fresh-cut market, the products will be washed prior to cutting.

Other questions on distribution & retail and systems in place to ensure safety of products are of horizontal nature and apply to all fresh produce categories. The responses to these questions are available in a separate document.

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19 July 2013

Background information distribution & food safety practices

Distribution & retail (questions 21-24)

(21) No particular transport and distribution conditions apply for leafy greens destined for fresh market (i.e. transport under ambient temperature), for quality reasons many operators will nevertheless try to ensure the cold chain, particular for long haul transport (<10°C). In the case of fresh-cut, transport and distribution need to take place under regulated temperature. The practices vary per country and are fixed in national legislation (BE, DE, NL: <7°C, FR: 1-4°C, IT: <6°C, SE: 2-5°C). In general operators will apply lower temperatures to optimise quality and shelf life. Some species (e.g. herbs),however, do not support such lower temperatures.

(22) The control of the cold chain will be under the responsibility of the manufacturer until the delivery, whereby the temperature will be checked during loading and unloading of the truck as well as being registered during transport. From delivery until the purchase by the consumer, the control of the cold chain will be under the responsibility of the retailer. In the case of long term storage (e.g. cabbage, carrots, onions), cabbage and carrots are stored in cold stores whereby temperature and moisture are set. Onions are stored similarly to potatoes in ventilated cold stores whereby sprout suppressants are used.

(23) All vegetables for the fresh market may be sold under ambient temperature. In general most vegetables will however be sold under regulated temperature to maintain quality and ensure longer shelf life. Fresh-cut produce may only be sold under regulated temperature (see also question 21).

(24) Traceability: see presentation

Food safety systems (questions 25-42)

(25-26) Guidelines for good hygiene practices in fresh produce are available at national level, with separate guidance for primary production, distribution & trade as well as processing (fresh-cut). All guidance documents are generic and apply to both fruit and vegetables, although they include specific provisions for certain product categories where needed.

EU guidelines are not available, private certification systems (e.g. GlobalGAP, QS, IFS, BRC, ...) however provide a broader scope.

The main strength of these schemes consists in the identification of hazards and establishment of preventive measures from field to distribution. A weakness in the guidelines on primary production is the lack of attention to microbiological and emerging risks. These are however gradually being addressed.

(27) Major weak points in agricultural production system include the irrigation with surface

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water, contamination by pests or animals and contact with the soil for certain salad types. The principal weak point for fresh-cut produce is a possible major rupture of the cold chain after delivery.

(28) EU Hygiene rules (Reg. 852/2004) require the registration as food processing establishment of any company producing fresh-cut produce. The hygienic requirements these companies need to comply with are provided in Annex II which are further clarified in national good hygiene practices guidelines or private certification schemes. Control of these requirements take place through control plans, internal and external audits as well as official inspections.

(29) There is no central repository of non-compliances at EU or national level. Generally companies analyse non-compliances in order to improve their practices. Some national industry associations pool microbiological test results on fresh produce as well as chlorine data to enable collective improvement actions or monitor the state of play regarding pathogens for which no microbiological criteria have been established.

(30) Positive release schemes are not used in the fresh-cut segment given the short shelf life of fresh-cut produce and the time needed for microbiological analysis.

(31) Producers and producer associations do carry out regular testing, a microbiological control plan is defined by each party involved in primary production. A retail level a random control plan is implemented.

(32) Sampling plans for microbiological testing/monitoring are defined in the legislation and are set by each food business operator on the basis of a risk analysis.

(33 and 37-38) Imported produce is treated similarly to EU produce and is not subject to additional testing or specific other hygiene requirements.

(34) Freshfel does not have centralised data available regarding the detection of Salmonella and Norovirus on leafy greens, or Salmonella, Yersinia, Shigella and Norovirus on bulb and stem vegetables and carrots.

The French fresh-cut industry association (SFPAE) collected data for Salmonella on leafy greens, from 2010 to 2012 more than 1.000 samples per year (all negative). The association is also carrying out further research regarding norovirus (results expected in 2014).

Belgium, Germany and the Netherlands have set-up a monitoring scheme for various fruit and vegetables which will be implemented in the coming months.

(35) Detection methods being used:

- Salmonella: NEN-EN-ISO 6579:2002, BRD 07/11-12/05, Rapid Salmo AES 10/4-05/04
- Norovirus: no validated method to date (research French association SFPAE)
- Shigella: NEN-EN-ISO 21567:2004
- Yersinia: NEN-EN-ISO 10273:2003

Commercial kits are sporadically used, generally companies prefer accredited methods in order to avoid discussions in case of complaints.
Commonly vegetables in the fresh-cut segment are tested on Salmonella, E. Coli and Listeria; other pathogens may be tested for on specific request of customers.

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(36) There is no difference in hygienic requirements for the production of organic versus conventional leafy greens.

(39) Decontamination methods used in primary production:

- Soil treatment: Metam-sodium, Dazomet, 1,3-Dichloropropone, steam, solarisation
- Manure treatment: composting

These treatments are primarily meant to combat pests (nematicide) and disease, and limit weed competition (herbicide). Assurance schemes generally recommend to maximise the time between manure application and harvest. GlobalGAP recommends untreated organic fertiliser should not be used from 60 days previous to the harvest season.

(40) Water treatment methods:

- Water reservoir: mostly no treatment, where allowed oxidative or copper compounds as well as chlorine
- Irrigation system: chlorydric acid
- Processing water
  - Chemical: chlorine solutions; ozone; peracetic acid
  - Physical: UV-light, ultrasound

(41) Decontamination methods of produce:

- Chemical: not available
- Physical: grading (optical and visual), recovery of foreign bodies by difference in density in the cleaning trays, leaching during the cleaning process, rinsing with drinking water

(42) Freshfel does not provide specific recommendations on methods used to reduce contamination by pathogens on fresh produce.

Key differences EU vs US fresh produce practices

- Preventive approach (GAP, GHP) EU versus curative approach US => disinfection in the field and of finished product
- Production concentrated in South West => transportation time =>longer shelf life (14-18 days vs 7-11 days in EU)
- Processing facilities near the production sites in US vs processing facilities nearby the consumer market in EU
- Transport under regulated temperature in EU vs transport with crushed ice (source of contamination) in US
- Presence of large cattle farms with flood washing systems nearby rivers which are used for irrigation in US
- Scale of operators is much larger in US vs EU
- Larger market penetration of fresh-cut produce in US vs EU

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Appendix B. Tomatoes production statistics tables (EUROSTAT, FAOSTAT) provided by Freshfel

Table 4: Tomato (fresh and industry destination) production in metric tons (Eurostat)

Producing country	2007	2008	2009	2010	2011	2012
Italy	6 530 162	5 976 912	6 878 161	6 024 800	5 950 215	5 131 977
Spain	4 081 477	4 049 753	4 798 053	4 312 709	3 864 120	4 007 000
Portugal	1 236 235	1 147 600	1 346 702	1 406 100	1 245 364	1 392 700
Greece	1 464 844	1 338 600	1 561 311	1 406 200	1 169 900	979 600
The Netherlands	685 000	730 000	800 000	815 000	815 000	805 000
Poland	689 719	702 546	709 223	558 064	712 295	758 936
Romania	640 785	814 376	755 596	768 532	910 978	683 282
France	575 428	617 629	654 390	645 194	597 471	588 660
Extra-EU28	476 840	478 760	530 219	502 920	464 764	445 365
Belgium	222 600	226 200	232 100	227 680	218 435	231 800
Hungary	227 600	205 597	192 810	134 274	163 349	108 799
Bulgaria	133 188	134 131	104 234	114 605	103 145	94 016
The United Kingdom	85 600	88 690	86 800	89 320	89 800	83 500
Germany	62 599	65 096	66 620	73 285	76 718	61 188
Austria	44 922	42 109	41 513	44 241	50 389	52 032
Finland	38 171	40 467	38 383	39 198	40 163	38 347
Croatia	48 076	32 358	37 419	33 648	35 798	25 418
Sweden	16 400	16 200	13 600	13 800	13 543	14 500
Cyprus	29 386	23 443	20 323	18 315	14 835	14 315
Ireland	12 000	12 005	12 500	13 000	13 221	14 000
The Czech Republic	29 771	27 899	14 755	7 238	15 518	13 317
Denmark	20 000	20 009	20 000	15 000	13 241	13 270
Lithuania	1 310	1 357	1 574	2 400	2 000	11 600
Malta	14 841	15 746	11 566	14 572	13 953	11 142
Slovenia	4 400	4 704	4 344	3 766	5 512	7 313
Slovakia	55 154	56 585	51 883	36 457	6 580	6 580
Latvia	7 300	4 700	4 600	5 307	7 908	5 718
Estonia	6 800	5 392	4 699	5 184	6 414	4 771
Luxembourg	85	83	75	71	64	84
Total	**17 440 693**	**16 878 947**	**18 993 453**	**17 330 880**	**16 620 693**	**15 604 230**

Table 5: Import from extra-EU in metric tons (Eurostat)

Exporting country	2007	2008	2009	2010	2011	2012
Morocco	302 389	305 963	354 701	308 078	335 353	347 353
Turkey	94 215	99 418	105 458	111 888	54 993	43 777
Israel	26 761	19 062	25 243	23 697	18 704	12 262
Senegal	7 300	8 824	6 893	8 758	9 625	9 582
FYROM[(a)]	21 345	28 365	16 747	20 591	11 167	8 783
Tunisia	3 161	4 019	7 189	9 850	11 599	8 563
Albania	88	120	781	3 239	3 734	5 903
Jordan	3 227	5 105	4 116	6 925	12 851	2 889
Egypt	2 372	2 679	2 959	3 719	2 669	2 578
Serbia	2 875	1 464	449	2 337	132	1 336
Dominican Republic	120	130	309	964	873	1 209
Occupied Palestinian Territory	281	84	249	244	191	292
Bosnia and Herzegovina	836	275	343	558	858	231
Costa Rica	31	NR	14	20	9	132
Belarus	NR	NR	NR	6	19	88
Mexico	NR	0	NR	NR	NR	85
Syria	10 955	2 509	4 468	1 284	368	83
Other	884	744	300	763	1 621	219
Total	**476 840**	**478 760**	**530 219**	**502 920**	**464 764**	**445 365**

NR: Not reported
(a): Former Yugoslav Republic of Macedonia

Table 6: Import from intra-EU in metric tons (Eurostat)

Importing country	2007	2008	2009	2010	2011	2012
Germany	702 327	691 181	684 885	709 274	709 997	709 033
The United Kingdom	410 137	406 281	375 439	363 436	383 468	374 338
France	219 334	219 520	240 659	229 628	223 433	251 358
The Netherlands	187 854	159 847	170 112	166 062	188 136	187 002
Spain	220 027	160 349	161 913	142 933	126 098	129 115
Italy	81 922	84 511	118 400	87 409	123 173	128 732
Poland	77 422	105 482	96 712	94 131	116 944	109 851
The Czech Republic	87 921	94 371	94 084	87 134	98 760	88 332
Lithuania	33 278	52 484	35 059	44 092	60 883	87 531
Sweden	83 576	85 014	85 437	85 529	89 428	86 486
Belgium	68 849	81 452	71 856	72 710	75 750	83 033
Austria	44 699	42 225	40 713	46 167	45 791	44 421
Denmark	36 555	36 117	40 997	38 758	35 644	36 133
Portugal	32 607	29 762	35 183	32 478	36 586	30 057
Slovakia	22 515	33 611	28 534	26 460	29 217	28 471
Ireland	36 130	36 054	34 891	29 945	26 236	26 401
Finland	21 832	23 264	24 345	22 478	24 196	25 469
Romania	11 539	17 049	13 773	8 829	12 186	20 878
Bulgaria	2 070	2 836	2 968	8 614	13 999	18 054
Latvia	15 991	19 156	15 225	12 351	17 604	16 945
Slovenia	13 348	15 469	13 420	12 412	12 733	11 707
Estonia	10 737	11 803	13 070	10 799	12 015	11 589
Greece	14 680	10 804	10 824	10 054	7 818	9 556
Hungary	12 477	14 928	11 852	12 040	11 710	8 167
Croatia	6 409	6 900	4 118	3 720	5 259	6 945
Luxembourg	5 317	5 032	5 068	5 350	5 157	5 014
Malta	273	377	1 046	740	823	943
Cyprus	143	383	155	540	627	754
TOTAL	**2 459 966**	**2 446 257**	**2 430 736**	**2 364 072**	**2 493 672**	**2 536 318**

GLOSSARY

Clean water is clean seawater (natural, artificial or purified seawater or brackish water that does not contain micro-organisms, harmful substances or toxic marine plankton in quantities capable of directly or indirectly affecting the health quality of food) and fresh water of a similar quality (Regulation (EC) No 852/2004)[22].

Decontamination treatments are mechanical, physical, and chemical treatments, which are applied to eliminate contaminants, including microbial contamination. They can be applied to water, surfaces, equipment and areas.

Disinfectants are agents or systems that kill or eliminate bacteria found on inanimate surfaces or environments. Within this opinion, disinfectant agents or systems are defined as those decontamination agents applied to eliminate micro-organisms in wash water.

Fertigation is the application of fertilizers, soil amendments, or other water-soluble products through an irrigation system.

Food of non-animal origin include those derived from plants and comprise a wide range of fruit, vegetables, salads, juices, seeds, nuts, cereals, herbs, spices, fungi and algae, which are commonly consumed in a variety of forms. Categorisation of FoNAO, as considered in the scope of this Opinion, is discussed in Chapter 2.2 of EFSA Panel on Biological Hazards (BIOHAZ) (2013).

Flume is an artificial channel of water where the flowing water is used to transport materials, such as fruits.

Food Safety Criteria are defined in EU legislation for the microbiological acceptability of food products and are criteria defining the acceptability of a product or a batch of foodstuff applicable to products placed on the market (Regulation (EC) No 2073/2005)[23]. If a Food Safety Criterion is not met for a product or batch of foodstuff, then this should not be placed on the market or, if it already has, be considered for recall.

Fresh Produce refers to fresh fruits and vegetables that are likely to be sold to consumers in an unprocessed or minimally processed (i.e. raw) form and are generally considered as perishable. Fresh produce may be intact, such as strawberries, whole carrots, radishes, and fresh market tomatoes, or cut during harvesting, such as celery, broccoli, and cauliflower[24]. In the scope of this opinion fresh produce also applies to fresh-cut produce, such as pre-cut, packaged, ready-to-eat salad mixes.

Fungicide is a specific type of pesticide that controls fungal diseases by specifically inhibiting or killing the fungus or fungal spores.

Good Agricultural Practices (GAP) apply available knowledge to address environmental, economic and social sustainability for on-farm production and post-production processes resulting in safe and healthy food and non-food agricultural products (FAO, 2003).

Good Hygiene Practices (GHP) relate to general, basic conditions for hygienic production of a foodstuff, including requirements for hygienic design, construction and operation of the plant,

[22] Regulation (EC) No 852/2004 of the European Parliament and of the Council of 29 April 2004 on the hygiene of foodstuffs. OJ L 139, 30.4.2004, p.1-54.
[23] Commission Regulation (EC) No 2073/2005 of 15 November 2005 on microbiological criteria for foodstuffs. OJ L 338, 22.12.2005, p.1-26.
[24] FDA Guidance for Industry: guide to minimize microbial food safety hazards for fresh fruits and vegetables. 1998. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/ProducePlantProducts/ucm064574.htm

hygienic construction and use of equipment, scheduled maintenance and cleaning, and personnel training and hygiene. A developed and implemented GHP programme is a pre-requisite for HACCP system (EFSA, 2005).

Good Manufacturing Practices (GMP) cover the principles needed to design plant layout, equipment and procedures for the production of safe food. This includes hygienic operation and cleaning and disinfection procedures. The codes and requirements may be formally specified by e.g. Codex Alimentarius Committee on Food Hygiene (EFSA, 2005).

Harvest is the process of collecting mature crops from the fields and immediate handling.

Hygiene Criteria are criteria indicating the acceptable functioning at pre-harvest, harvest and on farm post-harvest production prior to processing and are proposed to verify and validate Good Agricultural Practices (GAP) and Good Hygiene Practices (GHP).

Hydro-cooling is one of several post-harvest cooling methods available to growers, packers, and shippers to reduce the temperature of the crops. This technique consist in dumping produce into cold water, or running cold water over produce to remove heat.

Hydro-coolers produce chilled water and then move this water into contact with the produce.

Hydroponic culture represents a type of soil-less growing system where fertilizer ingredients are in solution in the root environment of the plants, and any solid media in the plant root environment will not significantly interact with the fertilizer in the water of the system. The plants in the system absorb the nutrients they need for growth from the water available in the root environment. Common solid media used in hydroponic culture include perlite and rockwool. Soil is not used in a hydroponic system (Brown, online).

Minimal processing is any action applied to the initial product (e.g. cleaning, coring, peeling, chopping, slicing or dicing and washing) and which is not included below in the definition of processing (e.g. heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes). Minimal processing may occur at harvest as well as on farm post-harvest and at processing.

Osmoticum is any substance that acts to supplement osmotic potential.

Pericarp is the ripened and variously modified walls of a plant ovary. In tomato fruits, the pericarp comprises the epidermis and the fleshy tissue.

Pesticides cover insecticides, acaricides, herbicides, fungicides, plant growth regulators, rodenticides, biocides and veterinary medicines. Pesticides are chemical compounds: a substance or mixture of substances, or micro-organisms including viruses used in plant protection to: (i) kill, repel or control pests to protect crops before and after harvest; (ii) influence the life processes of plants; (iii) destroy weeds or prevent their growth; (iv) preserve plant products[25].

Potable water is water which meets the requirements laid down in Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (mainly microbiological and chemical criteria) (Regulation (EC) No 852/2004).

Post-harvest is the stage of crop production after harvest and includes on-farm cooling, cleaning, sorting and packing.

Pre-harvest incorporates all activities on the farm that occur before crop products are harvested.

[25] Based upon definition available at http://ec.europa.eu/food/plant/plant_protection_products/index_en.htm

Process Hygiene Criteria are criteria indicating the acceptable functioning of the production process. Such criteria are not applicable to products placed on the market. They set an indicative contamination value above which corrective actions are required in order to maintain the hygiene of the process in compliance with food law (Regulation (EC) No 2073/2005).

Processing are any actions that substantially alter the initial product, including heating, smoking, curing, maturing, drying, marinating, extraction, extrusion or a combination of those processes (Regulation (EC) No 852/2004).

Ready-to-eat food: food intended by the producer or the manufacturer for direct human consumption without the need for cooking or other processing effective to eliminate or reduce to an acceptable level micro-organisms of concern (Regulation (EC) No 2073/2005).

Sanitizers are chemical agents that reduce micro-organisms on food contact surfaces to levels considered safe from a public health viewpoint. Appropriate sanitization procedures are processes, and, thus, the duration or time as well as the chemical conditions must be described. In some cases, the definition of sanitizing refers a process which reduces the contamination level by 99.999 % (5 logs). Within this Opinion sanitizers are defined as those decontamination agents applied to reduce the level of micro-organisms on tomatoes.

Soil-less cultures are various methods and techniques developed for growing plants without soil. These methods include a great diversity of systems, from the purely hydroponic, which are based on the supply of water and nutrients only (e.g. nutrient film technique, or NFT), to those based on artificial mixes that contain various proportions of soil. In between these extremes lie a great number of soil-less or minimal soil methods that make use of some sort of growth medium, which is either inert (e.g. rockwool slabs, polyurethane chunks, and perlite) or not inert (e.g. gravel culture, sand culture, and peat bags) (Papadopoulos, 1991)